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Ferro-cement boat

CONSTRUCTION OF A 16-METRE FERRO-CEMENT FISHING BOAT

by

J. Fyson

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1970

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CONSTRUCTION OF A 16-METRE FERRO-CEMENT FISHING BOAT

by

John F. Fyson
FAO/TA Boatbuilding Superintendent

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, December 1970

PREPARATION OF THIS REPORT

The report describes the construction in Thailand of a prototype 16 metre ferro-cement fishing boat by the Fisheries Department of Thailand under the supervision of an FAO Boatbuilder within the framework of FAO/UNDP Technical Assistance for fishing boat development.

Distribution:

FAO Department of Fisheries
FAO Regional Fishery Officers
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"Current bibliography" entry:

Fyson, J.F. (1970) 17-5M029
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Construction of a 16-metre ferro-cement fishing boat

Thailand - ISEW. Fishing technology, vessels. Design - technical details. Cost analysis. Experimental trials.

CONTENTS

DRAWINGS

1. INTRODUCTION

With the increasing cost of wood in most countries in which ferro-cement is used for fishing boat construction and the large amount of skilled handwork required in the construction of a wooden fishing boat, FAO has for some time been interested in the possibility of other methods of building strong and economical fishing boats while using the minimum of skilled labour. The potential of ferro-cement (F/C) for fishing boats has not been very widely appreciated and it was decided that further investigation into the method should be made.

During a period of home leave the author was able to investigate amateur and commercial F/C vessels built in New Zealand, one of the first countries where this material was developed from the initial experiments of Professor Nervi, Italy. On return to Thailand, where the author was stationed as FAO/TA Boatbuilding Superintendent, a study of all the available publications on the subject was made and with the information gained a report on F/C construction was written. Thus "Ferro-Cement Construction for Fishing Vessels" Fyson (1968) was published by "Fishing News International" in three issues, April - June 1968.

This report emphasized the low capital investment needed to set up a boatyard, the ready availability in most countries of the necessary materials and the high proportion of unskilled labour which could be used for this type of construction. As these factors correspond very closely to the basic requirements needed to set up a boatbuilding industry in a developing country - particularly one with no tradition of wooden boatbuilding, it was decided to carry the investigation further by building a fishing boat which could be subjected to extensive trials in the normal fishing operations.

The Fisheries Department of Thailand, seeing the possibilities of the material in a country where wood was increasing quite rapidly in price, provided the means to build a small vessel at the Rayong Marine Fisheries Station on the eastern coast of the Gulf of Thailand. Cost of materials was to be provided from the budget and the labour from the staff of the fisheries station. Initial cost estimates indicated that the maximum size of vessel which could be built in the station within the limits of the budget was a vessel of 16 m (52'6") LOA.

A project request was submitted to the Freedom From Hunger Campaign for the provision of a marine engine and associated equipment, and due to the experimental nature of the project and the possibilities of demonstrating the use of this material for fishing vessel construction, the FFHC obtained the donation of an engine from the Caterpillar Tractor Company of Illinois, USA, who very generously provided a complete D330C marine engine and ancillary equipment for the use of the project.

2. DESIGN

It was decided after consultation with the officials of the Fisheries Department that the vessel to be built would be based at the Rayong Marine Fisheries Station and used as a research and exploration vessel with a radius of operation of about 300 miles. The principal fishing method would be stern trawling with the possibility of converting to purse seining and gill netting. The crew requirement would be kept to a minimum sufficient to operate the boat and handle a stern trawl of 43.00 m (141 ft) total length, with a headrope length of 28.6 m (88 ft) and footrope 34.14 m (112 ft). Accommodation would be provided for a total of six persons; crew plus, on occasion, a biologist and a gear technologist. As much as possible of the accommodation would be above main deck level.

Due to the restricted depth of water at the launching site and the need to bring the vessel into an artificial basin with a mean high water level of 1.75 m (5'9") the design draft had to be kept to a maximum of 1.65 m (5'5").

The fish hold capacity was to be about 20 m^3 and a good sized gear store was also included at the expense of increased fish hold capacity, as the vessel was not intended to make commercial catches of fish.

For a small fishing vessel to be operated by a minimum crew, it was considered necessary to have visual and/or direct voice contact between the steering position and the winch and for the helmsman at the wheel to be able to see the angle of lead of the warps without having to step outside the wheel house. With these considerations in mind together with the need to site most of the accommodation above the main deck for coolness in tropical conditions, the layout shown in Fig. 1 was adopted. With the winch offset and the connecting doors open, the helmsman at the wheel has both visual and voice contact with the winch man and can see the lead of warp through the window on the starboard side of the after cabin bulkhead.

To cut down manpower needed in hauling the net, a trawl drum is located on the port side aft. Financial considerations eliminated the possibility of using a hydraulic drive for this drum so that the winch and drum are positioned to allow a rope drive which is considered adequate for the size of trawl to be used. A stern roller was fitted as an additional aid in bringing in the net.

Principal dimensions were finalized as:

Length over all (LOA)	16.00 m (52'6")
Length design waterline (DWL)	14.50 m (47'7 3/4")
Beam (maximum)	4.54 m (14'10 3/4")
Beam (waterline)	4.42 m (14'6")
Depth	2.25 m (7'4 3/4")
Displacement to design waterline (DWL)	34.5 m^3 (1,218 ft^3)

The lines were drawn with well radiused bilge curves, and flat sections were avoided as much as possible in order to facilitate construction, and to take advantage of the greater load bearing capacity of curved thin shells. Flatter sections in the forebody were reinforced with additional rods.

At the time the design of this vessel was undertaken, very little work had been published on the testing and strength characteristics of F/C. However it was obvious, from Nervi's original published work (Il ferro-cemento: sue caratteristiche e possibilitâ - L'Ingegnere 1951 N1), and following on from this, a series of experiments designed to produce values for mechanical properties of F/C by L.D. Collen, (Some experiments in design and construction with F/C - Institution of Civil Engineers of Ireland, Jan. 1960), that the most important single factor in producing a F/C shell of sufficient strength and flexibility for use in boat building was the steel content per unit weight of F/C.

On the basis of information available in these two papers a steel content of 480 kg/m^3 (30 lbs/ft^3) was chosen: this steel content to be of a number of layers of wire mesh and steel rods of approximately 6 mm (1/4") in diameter.

In order for the experiment to have a more immediate impact on the local fishing industry it was considered important to use, as far as possible, locally produced material, or those readily available on the local market. Investigation revealed that the only mesh types available were a hexagonal galvanized mesh of various gauges as well as small quantities of a galvanized welded square mesh.

Various grades of reinforcing rod such as is used in building construction were available but quality and strength characteristics varied widely from sample to sample. One of the better rods available in this class was a 6 mm wire rod produced locally to Japanese Standard Specification SS41. This steel gave, on test, a tensile strength of 9.8 kg/mm^2 (14,000 psi). An imported hard drawn steel wire of 6 mm (1/4") diameter was also available but only in short lengths and this, on test, gave a lower tensile strength of 8.9 kg/mm^2 (12,600 psi). Although hard drawn or high tensile steel rods are more suitable from the point of view of less distortion and better fairing, both the lower tensile strength and the short lengths, necessitating considerably more lapping of rods in the construction, excluded the imported hard drawn rod. The choice of the SS41 6 mm (1/4") rod was largely dictated by local supplies, and should high tensile, prestressing steel in the required diameters become readily available then this would be a better choice in the future.

Spacing of the steel rods in the F/C shell was decided on the basis of the need to achieve, in combination with the mesh layers, a total steel content of not less than 480 kg/m^3 (30 lbs/ft^3) as well as a concentration of additional steel in areas of high stress.

A number of the pleasure craft built in F/C, of which published accounts were available, used a single layer of 6 mm (1/4") steel rod placed longitudinally at 50-75 mm (2"-3") spacing. This was felt to be unsuitable for two reasons. Firstly, a rapid calculation showed that unless an excessive number of layers of heavy gauge mesh were used in conjuction with this rod there would be insufficient steel in the mortar to achieve the required 480 kg/m^3 (30 lb/ft^3) of reinforcement. Secondly, if only longitudinal rods were used then the mortar and wire mesh would be required to resist the vertical stresses caused by the motion of the vessel in waves. Concrete or mortar alone being weak in tension and the proposed number of layers of mesh not having sufficient strength in themselves to resist initial distortion, it was felt that such a disposition of rods was inadequate to prevent the risk of cracking with consequent corrosion problems. Consequently, a framework of longitudinal rods at 75 mm (3") centres joined by vertical rods at 100 mm (4") centres was chosen as the basic rod structure.

Three or four layers of mesh on each side of the rod framework was considered to be the most suitable configuration, and calculation of the weights of various samples of locally available mesh indicated that 4 layers per side of a 19 gauge 15 mm (5/8") galvanized, hexagonal mesh would provide the necessary steel content. Unfortunately there was no 12 mm (1/2") hexagonal mesh of a suitable gauge available at that time, and supplies of 12 mm (1/2") 19 gauge welded mesh were too limited to permit construction of the completed hull and deck in this material. It was therefore decided to use the hexagonal mesh for the compound curvature of the hull and retain the welded mesh for incorporation in the flatter surfaces of deck and bulkheads.

In order to have suitable data on which to base strength and weight calculations, it was decided at this stage to carry out a series of tests on panels of F/C made up using locally available materials. In this part of the work valuable assistance was given by the Applied Scientific Research Corporation of Thailand, who undertook to carry out a research project in cooperation with the Department of Fisheries to provide the necessary design information. Results of this project are provided in Research Project No. 21/14 Ferro-cement ASRCT Bangkok, 1969.

The time factor, and also a limited budget, prevented an exhaustive test programme, and investigation was limited to the testing of a range of mortar mixes incorporating various additives and using the two grades of mesh available on the framework of rods already selected. The cement used for the tests was a locally produced modified Portland Cement, type II, which possesses resistance to sulphate attack. A natural fine river sand from the area of construction was selected. This

sand was composed of particle sizes ranging from 3 mm (1/8") to 0.074 mm (1/320") with a grading curve ranging from 100% passing ASTM sieve number 8, to 5% passing ASTM sieve number 100. The use of a pozzolan to improve the sulphate resistant qualities of the cement mortar was considered, however no diatamaceous earth or similar natural pozzolan was available and the industrial fly ash which was procurable proved to have too high a sulphur content, with consequent injurious results on setting times and strength properties of the mortar. It was considered that the modified type II Portland cement was sufficiently sulphate resistant for the purpose, although a type V Portland cement, if available, would provide additional resistance against sulphate attack.

As cement/sand ratios, and especially water/cement ratios have a considerable influence on the properties of the mortar, a range of cement/sand ratios was tested and mixtures with commercial additives, designed to reduce the water content without losing workability, were added. Complete results of tests are available in the report referred to above, and it is sufficient here to indicate that the most suitable mixture, when judged both for economic advantage and sufficient strength, proved to be a mixture with the following components:

Sand/cement	1.75 : 1
Water/cement	0.36
Commercial plasticizing additive (lignosulphonate based)	7 cm^3/kg of cement.

A test panel composed of longitudinal 6 mm rods at 75 mm (3") centres, and transverse rods at 100 mm (4") centres with four layers of 19 gauge galvanized hexagonal mesh on either side have, with a mortar cover of 3 mm (1/8"), an average thickness of 25 mm (1"), with an average weight of 54 kg/m^2 (11 lbs/ft^2). Yield load was 559 kg (1254 lb), modules of rupture 208 kg/cm^2 (3014 lb/in^2) and modules of elasticity at initial tangent 0.172×10^6 kg/mm (2.48×10^6 lb/in^2).

3. CONSTRUCTION

3.1 Lofting

Lofting of the hull to full size was carried out in the usual way. In this case the profile, waterlines and buttocks were faired on a concrete floor using weights to hold the battens in place, while the sections were lofted on an area of portable wooden flooring as seen in Fig. 1. By making the lofting of the sections portable, it was possible to readily compare dimensions taken from the profile and waterlines with those of the sections and, when the lofting was completed, move the wooden flooring to a convenient position for the bending of pipe frames.

3.2 Bending of keel, stem and pipe frames

The stem and keel profile were formed from 11/2 ID water pipe, bent to shape, and then compared with the loft drawing to ensure accuracy. To aid in setting up, each station position was clearly marked on the keel and appropriate waterlines marked on the stem.

Pipe frames, fabricated from 18 mm (3/4") internal diameter (ID) water pipe, were bent to shape by hand around wooden blocks fastened temporarily to the loft floor. If available a pipe bender would be a useful time saver at this stage of construction. Fig. 2 shows a completed pipe frame, with its deck beam already bent to the correct camber and welded in place, being checked against the loft lines. Positions of waterlines are then marked on each frame to assist in setting up.

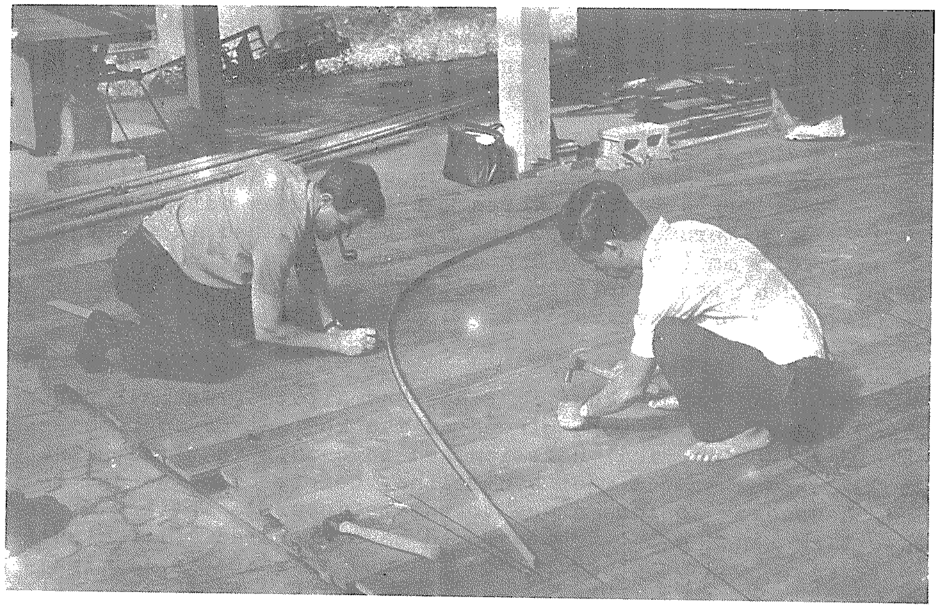


Fig. 1 Drawing the shape of the sections full size on the wooden loft floor.

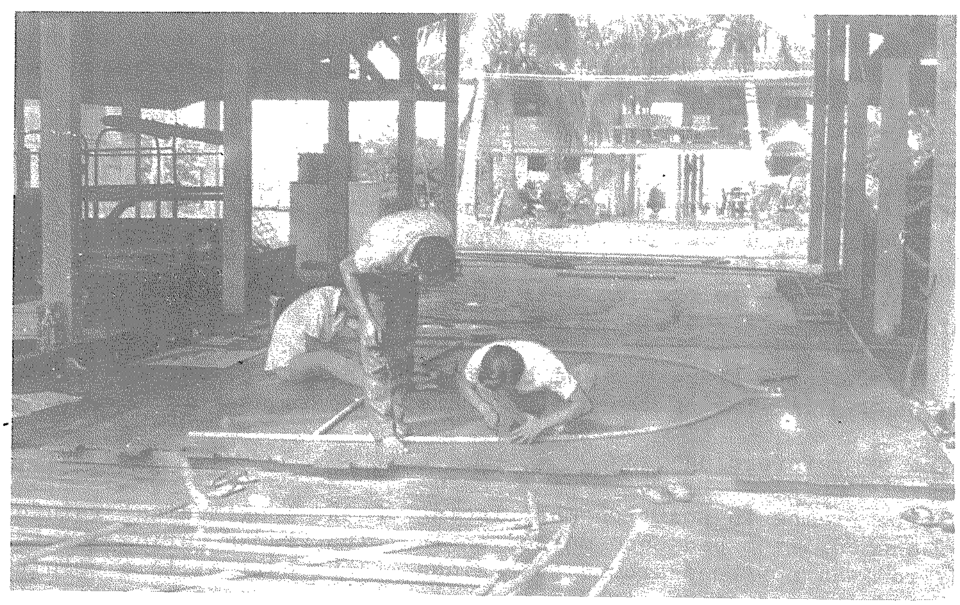


Fig. 2 Checking the shape of the pipe frames by comparing with the drawing.

3.3 Setting up

The first stage in setting up was the fastening of keel and stem in place on temporary blocks at the correct rake, verified against a cord drawn tight at a height representing the design waterline, see Fig. 3.

The stem was then fastened to the roof beams by offcuts of pipe welded in place to act as braces, while the keel itself was supported by additional sections of pipe, welded to the keel at every station. These vertical pipes served as reference points for the positioning of alternate frames (frames being placed at every 1/2 station, i.e. at a spacing of 725 mm (28 $\frac{1}{2}$ ")) and also as hanging supports for the complete framework when setting up was completed, and the temporary keel blocking removed. Details of the fastening of these vertical supports to the keel are shown in Figs. 5 and 9.

With the keel and stem braced in place and all the vertical support pipes in position, the individual frames were placed on the keel at the correct spacing, checked with a plumb-bob both for vertical position and to ensure that the plane of the frame was exactly at 90 degrees to the keel centreline, before being welded in position. Extreme care was necessary at this stage to ensure accurate setting up as otherwise unexpected distortions in the hull shape would have appeared after plastering. Unlike a wooden vessel, frames cannot of course be trimmed to shape to eliminate minor irregularities before planking. Figs. 4 and 5 show the process of setting up frames from the sternpost forward - note the increased radius given in the region of the sterntube. Fig. 6 shows a frame near the bow where the two pipe ends forming the frame have just been welded to the keel pipe while the vertical support pipe can be seen forward of the frame.

When the frames are in position and welded to the keel and the centre line (C/L) of the deck beam welded to the vertical support piping where appropriate, additional supports designed to help take the weight of the mortar during the plastering operation are welded from the top of the bulwark piping to the roof supports above. This is shown in Fig. 7. To avoid sagging of the pipe frames at the turn of the bilge, cross braces as shown in Fig. 8 were welded at alternate frames from the turn of the bilge back to the vertical support pipes where these are welded to the deck beams.

Fig. 9 shows a general view of the joining of frames to the keel pipe looking forward. Note that a cross bar was welded between the two arms of the frame in such a way that this pipe would rest on top of the keel pipe when the frame was set up in its correct position. A flat bar of 25 x 6 mm (1" x 1/4") steel was then welded under the two arms of the frame to provide a landing for the longitudinal rods which form the reinforcing of the keel bottom.

With all the pipe frames up and braced into position the lines of the hull begin to take shape. A view of the hull at this stage is seen in Fig. 10.

3.4 Placing of reinforcing rods

With pipe frames in position the placing of the longitudinal reinforcing rods was begun. The sheer line had been marked on the pipe frames during the lofting and a 6 mm (1/4") rod was now bent around both sides of the hull at this point, the line faired by eye and the rod tied into position with 18 gauge soft iron tie wire. Each pipe frame was then marked at 75 mm (3") intervals to five correct spacings for the longitudinal rods. These rods were then bent around the pipe frames and tied in place. Fig. 11 shows this work in progress and Fig. 12 shows a close up of rods tied to a pipe frame. Note that one of the rods is tied with a simple cross tie, which proved to be less satisfactory than the double ties used on the other rods and this latter method was adopted both for tying the rods to the frames and later for tying vertical rods to longitudinals.

Fig. 3 Setting up the stem and keel in the building shed.

Fig. 4 Fixing a frame in its correct position on the keel.

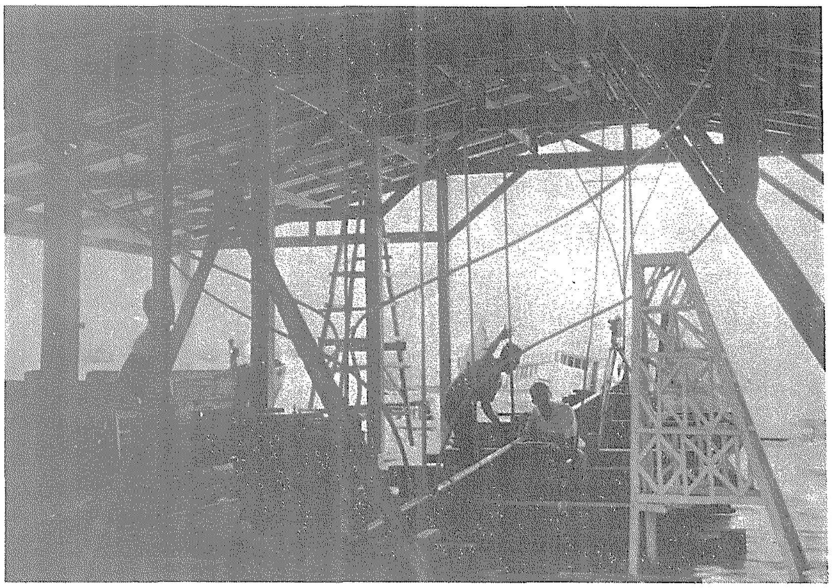


Fig. 5 View of frames and vertical supporting pipes as the setting up proceeds.

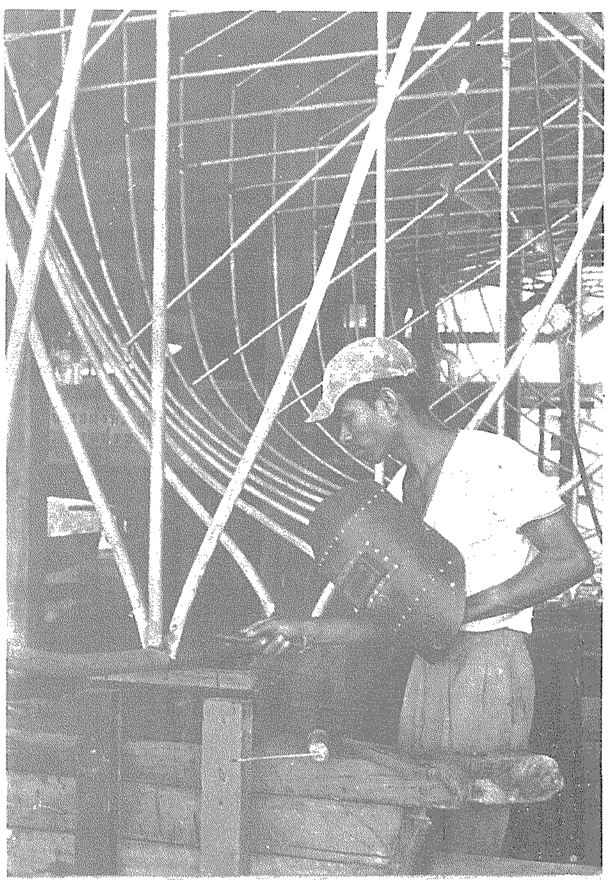


Fig. 6 Welding one of the forward frames to the keel.

Also seen in this detail are the ends of lapped rods. When two rods had to be joined they were lapped for a minimum length of 250 mm (10"), i.e. 40 diameters and a minimum of three ties were used in this length. At the stem the rods were bent around and welded to the stem pipe as seen in Fig. 13, while at the transom they were hooked around and welded to the transom frame.

Fig. 13 shows the completion of the longitudinal rods and the beginning of the tying in of the vertical rods in the first three frame bays. In Fig. 14 vertical rods are being bent around under the keel pipe and will then be lapped with other rods which complete the circuit of the hull by each vertical rod. A close up of a section of the keel after the horizontal and vertical rods were in place is seen in Fig. 15.

After the completion of this stage, extra longitudinal rods were laid so that the rod spacing on the keel bottom was 40 mm (1 ½") instead of the 75 mm (3") spacing used elsewhere. In areas of extra stress, such as in the region of bow and sternpost, additional vertical rods were also tied in to provide extra strength in these areas.

Figs. 16 and 17 show details of sternpost and "horntimber", the latter being another section of 40 mm (1 ½") ID pipe braced into place and welded to the correct angle with the sternpost. Note the extra radius in the pipe frame at the stern which is to accommodate the stern tube and still leave sufficient thickness of solid concrete inside the mesh to provide a suitable rigid sternpost. The wooden batten shown in Fig. 16 gives the line of the stern tube, and this was braced in place and cast in situ when pouring the sternpost concrete. Here again, extra rods were added to provide additional strength before the fastening on of the mesh.

With the reinforcing rods of the hull in place, the final step before laying the mesh was to weld to the pipe frames a series of lengths of 50 x 50 mm (2 x 2") angle iron. The purpose of this angle iron was threefold: firstly to provide a finishing line for the construction and casting of ferro-cement floors designed to reinforce and strongly tie together both sides of the hull; secondly to provide fixation points for removable wooden planks which would provide the flooring in each compartment of the hull; thirdly to act initially as convenient supports on which to place the temporary planking which would be necessary during the process of meshing and plastering. It is very important that supports be provided for workmen at this stage to avoid distortion of the hull during the plastering stage. Fig. 18 shows this angle iron in place. In the background can be seen the cut-away sections of the floors provided in the region of the engine bearers. Figs. 20, 21 and 23 show this in greater detail at later stages.

3.5 Tying of the mesh layers

Mesh was fastened to the inside of the hull first. Four layers were laid from bulwark to keel vertically, and tied in place with just sufficient ties to hold the mesh taut against the reinforcing rods. The mesh used was in rolls of 45 m (150 ft) long by 0.9 m (3 ft) wide and this was cut to suitable lengths. Joins between adjacent widths were made by laps 75-100 mm (3-4") wide, care being taken to stagger the laps from one layer to the next so that at no place was there a build up of more than 4 layers of mesh plus the additional layer of one lap. Too many layers concentrated at one place would cause an increase in thickness above the average, as well as making it difficult to force the mortar through the accumulation of mesh layers. This inside mesh was wrapped closely around the pipe frames and tightly tied in place, enclosing the pipe frames. Fig. 19 gives a close-up of a section of the hull with the four inner layers tied in place.

Note that the spacing of the vertical rods to the right of the pipe frame in Fig. 19 is at 50 mm (2") centres instead of the usual 100 mm (4") centres. This close-up is of an area in the bow which has been given additional reinforcing to allow for the greater stress on the relatively flat sections in this area, when the vessel is driving into a head sea.

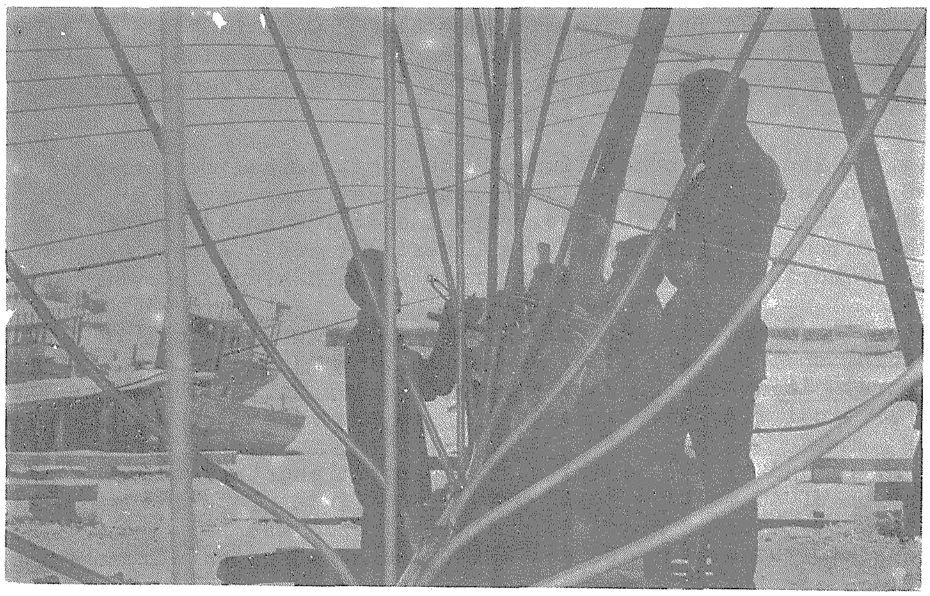


Fig. 11 Tying the first longitudinal rods in place.

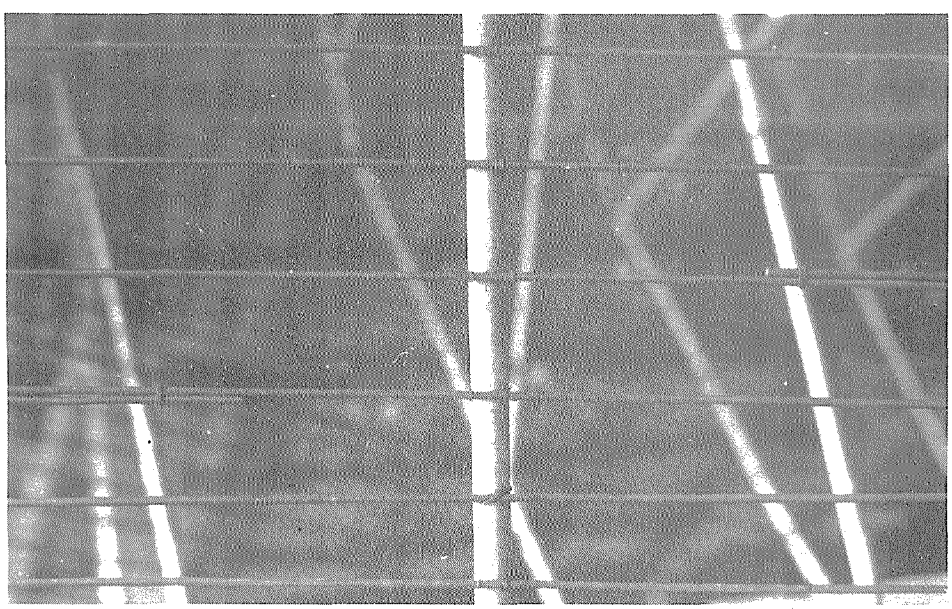


Fig. 12 Detail of longitudinal rods tied to a pipe frame.

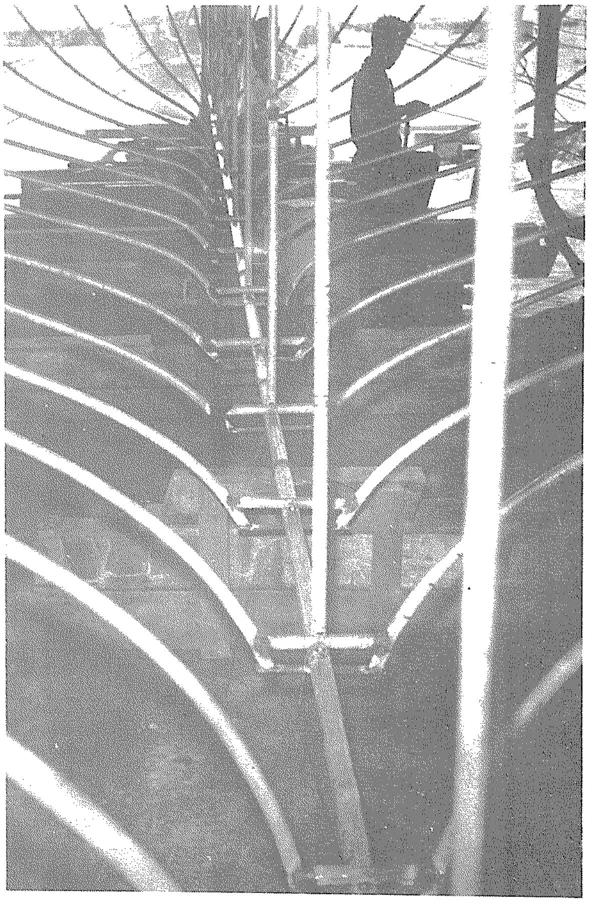
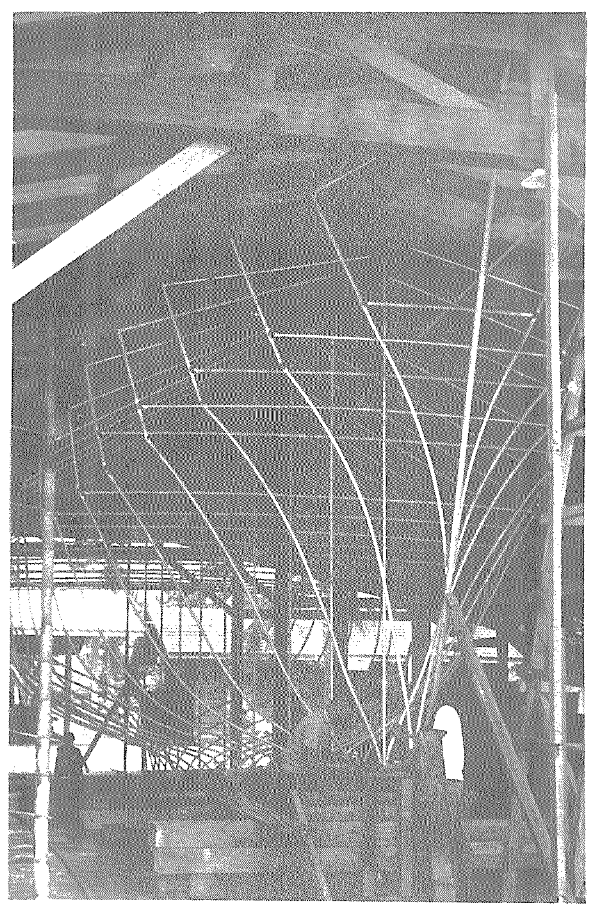


Fig. 9 Vertical supporting pipes and their attachment to keel and frames.

Fig. 10 View from the bow.



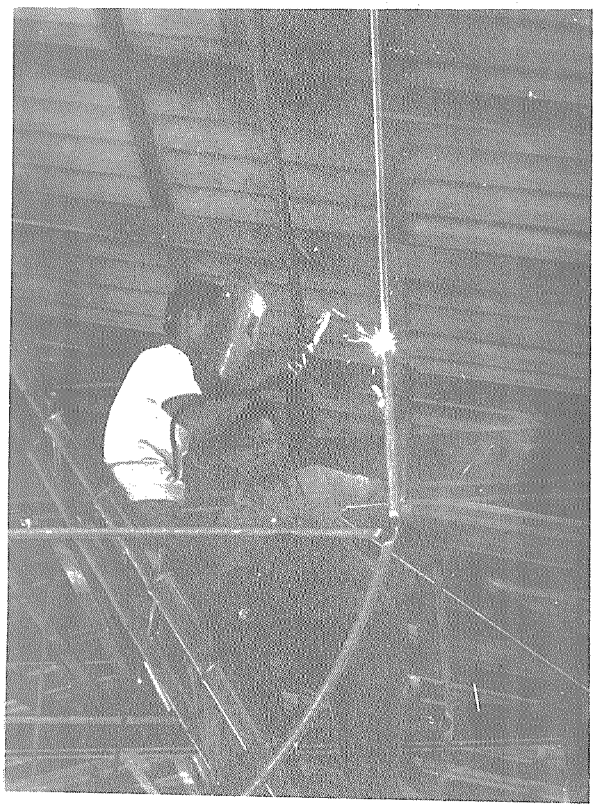


Fig. 7 Welding a support brace from the head of a frame to the roof.

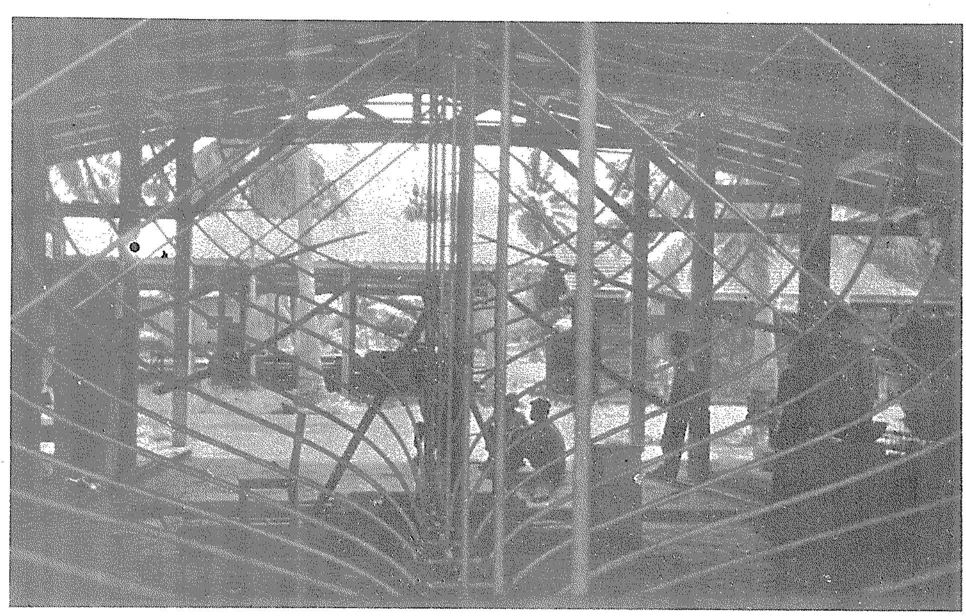


Fig. 8 View of the after part of the hull with all frames in place.

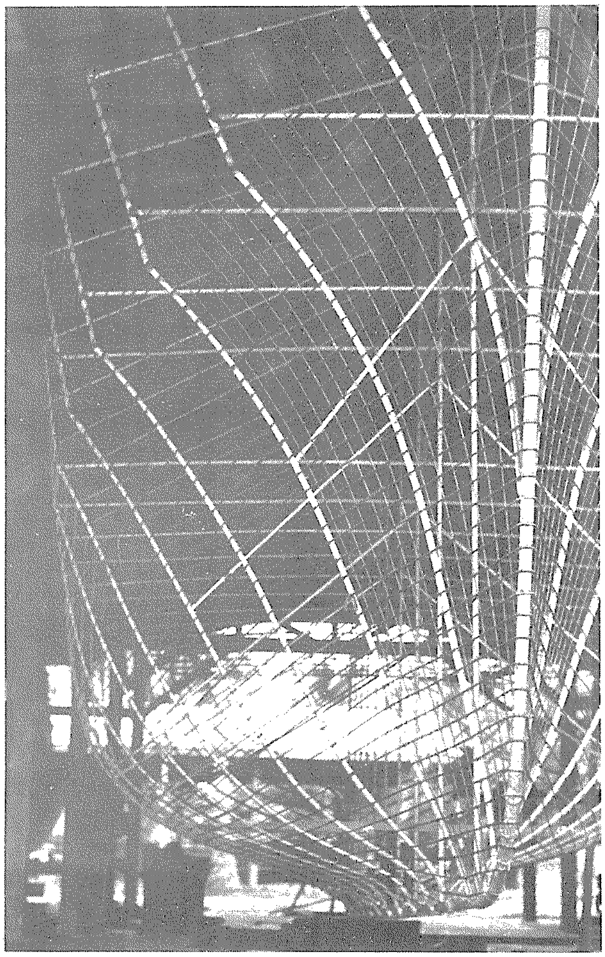


Fig. 13 All longitudinal rods in place, beginning the tying of vertical rods.

Fig. 14 Vertical rods being bent around the keel.

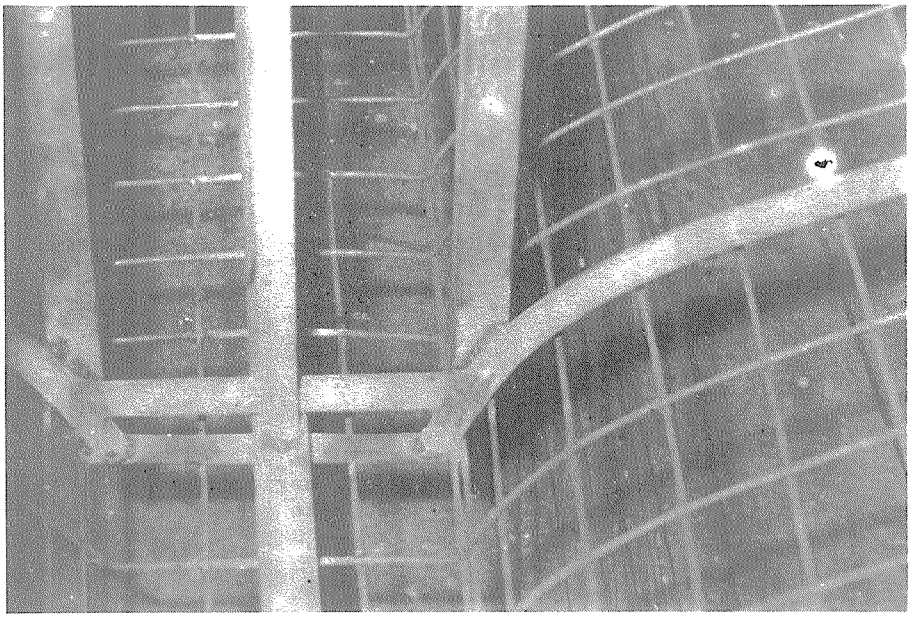
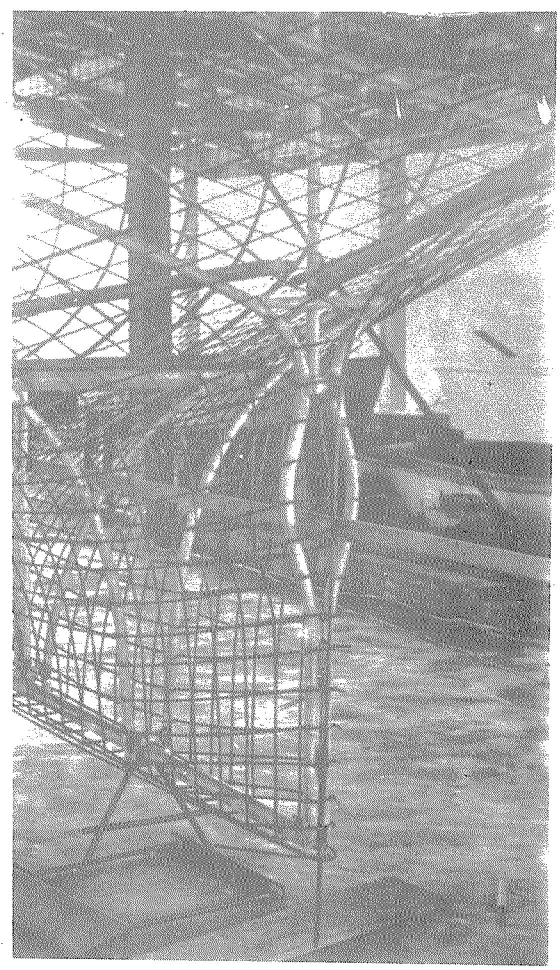


Fig. 15 Detail of rods in the keel area.

Fig. 16 The sternpost area with wooden batten marking the shaft line.



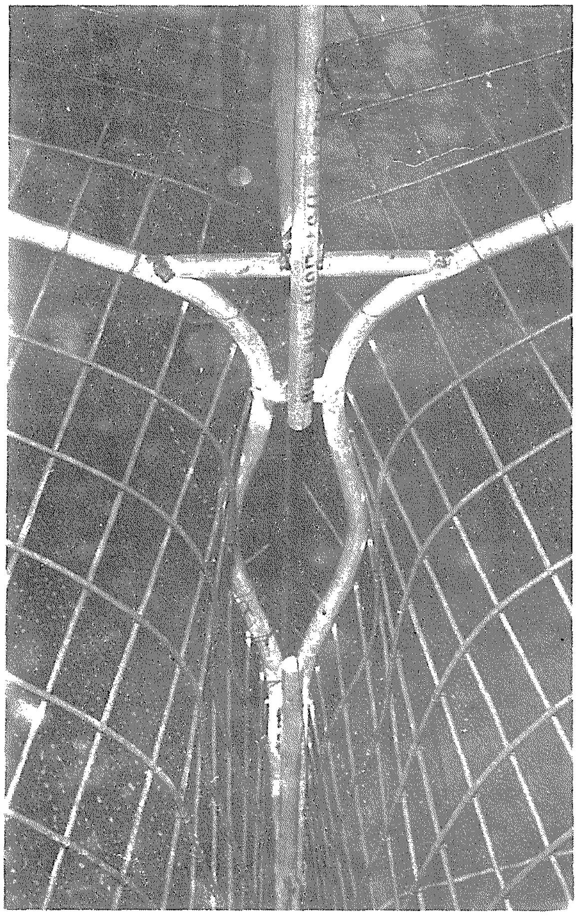
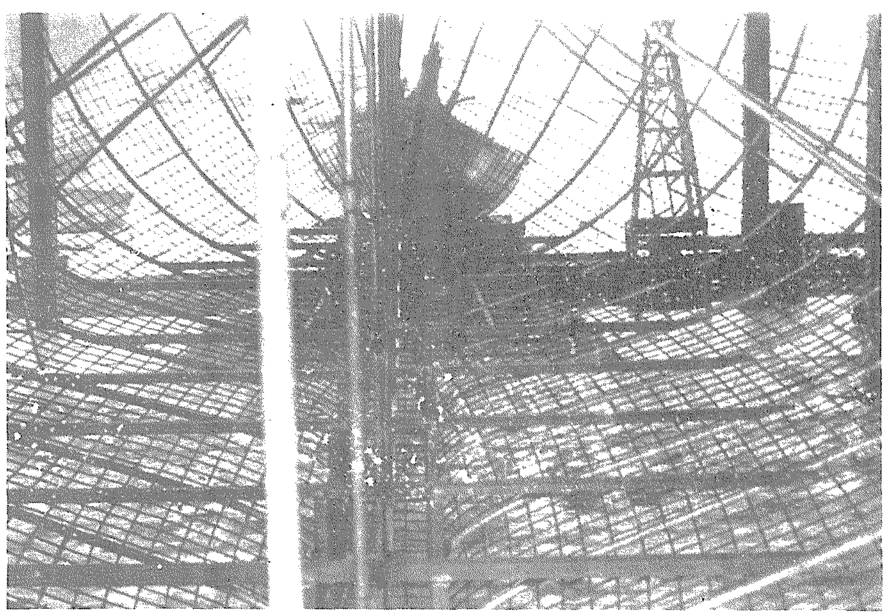


Fig. 17 Close up of Fig. 16. Additional vertical rods were added later.

Fig. 18 Interior of the hull showing the angle iron marking the tops of the floors.



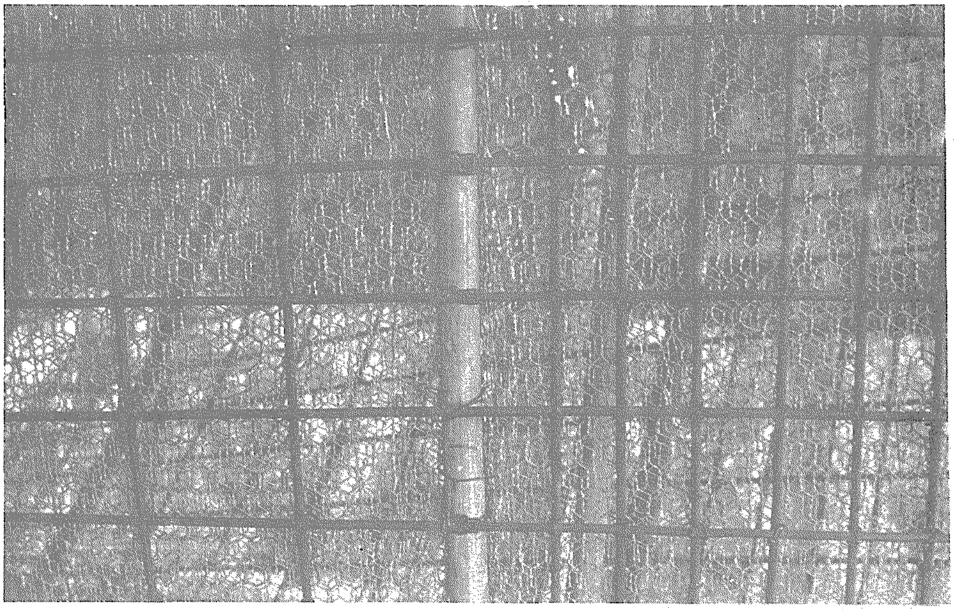


Fig. 19 The interior mesh in place. Note closer rod spacing towards bow.

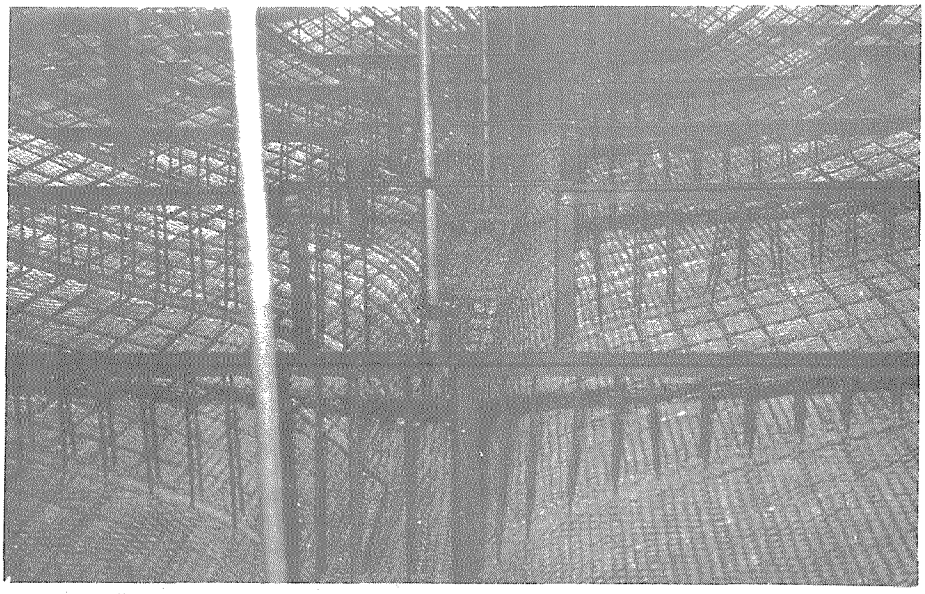


Fig. 20 Floors with vertical rods in place.

Fig. 21 Pushing the vertical rods through the inner mesh layers.

Fig. 22 Bending and tying these rods into place.

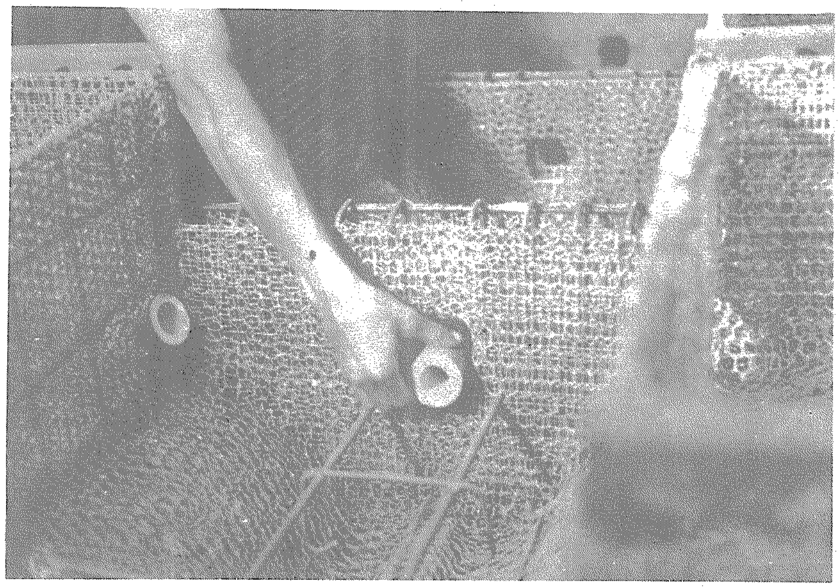


Fig. 23 Fitting bamboo plugs in the limber holes.

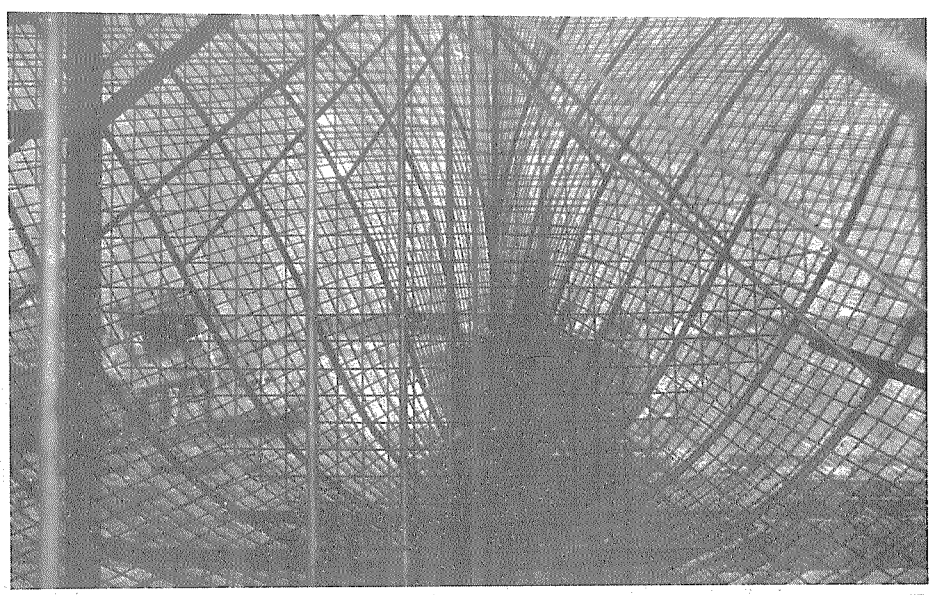


Fig. 24 The reinforcing rods of a vertical bulkhead.

3.6 Floors and bulkheads

When the inner layers of mesh were all tied in place work was started on the floors and bulkheads. For the floors, lengths of rod were bent in the form of a U to the desired width of floor 50, 75 or 100 mm (2, 3 or 4"), depending on location. The arms of the U are left longer than the desired depth of floor. These rods are then pushed through the layers of inside mesh with the arms allowed to protrude beyond the reinforcing rods. The arms are then bent back in line with the longitudinal reinforcing rods and tied to them with wire ties. Fig. 20 shows a general view of these U shaped rods in place to form the floors in the region of the engine bearers, while Figs. 21 and 22 show close-ups of the U shaped rods being pushed through the inner layers of mesh from the inside, and the arms being bent back in line with the longitudinal rods outside.

When this had been completed, transverse rods were tied in place and both sides of the floor thus formed covered with layers of mesh. Fig. 23 shows the completed floor in the region of the engine bearers. Note that the top of the floor was left open to allow the filling of the floor with mortar and the insertion of a vibrator to ensure complete penetration during the plastering stage.

To allow drainage of bilge water, limber holes are left in the mesh and bamboo plugs inserted to prevent the holes being filled during the vibrating and rodding of the mortar.

Bulkheads were formed by pushing horizontal and vertical rods through the mesh layers and bending the ends back in line with the longitudinal rods, as had already been done with the floors. Fig. 24 shows the horizontal and vertical rods in place before covering with mesh, while in Fig. 25 a workman is tying off bulkhead rods on the outside of the hull. Fig. 26 shows combined floor and bulk rods neatly tied off on the exterior of the hull. Note the pipe frame incorporated in the mesh layers.

The transom frame had not been covered with rods until this stage to facilitate the passing of mesh, rod lengths and tools into the hull. The reinforcing rods for this were then tied in place, strengthening webs at the C/L and 1 m (33") to port and starboard were formed of rod, and the inside of the transom covered with mesh. Fig. 27 shows the hull at this stage, with work ready to begin on the decks.

3.7 Decks and hatches

Longitudinal rods at 75 mm (3") centres were laid and tied to the deck beams. Transverse rods at 75 mm (3") centres were pushed through the mesh and tied on top of these longitudinal rods. Protruding ends of these rods were bent back and tied in place, as had been done for the bulkhead rods.

To avoid a sharp corner at the join between deck and hull, curved sections of rod were tied in place to form a radius, as shown in Fig.28 . Fig.30 shows a general view of the deck rods in place, with hatch openings cut but before the formation of the reinforcing rod coamings.

After the mesh on the underside of the deck had been tied in place the upper layers were laid and tied. Fig. 29 shows a layer of square welded mesh being laid on the deck to form the side of a hatch coaming.

At this stage lengths of 100 x 50 mm (4 x 2") channel iron were bent to the required deck curve, placed under the deck, and held in place by short lengths of rod welded to the deck reinforcement. The purpose of this channel was to provide a quick, cheap and relatively light under-deck reinforcement, to which heavily stressed deck fittings such as the winch, trawl warp, lead blocks, etc., could be fastened by through bolting.

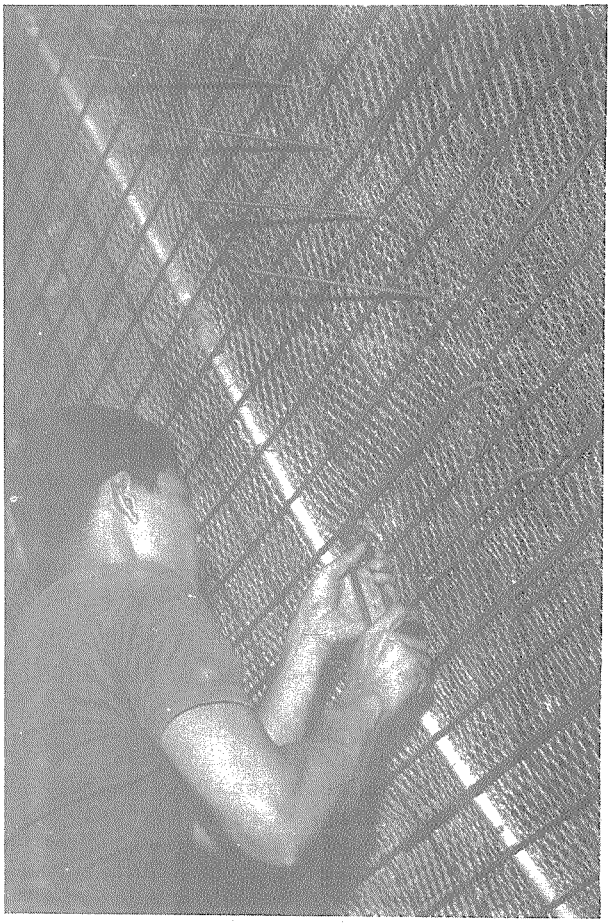
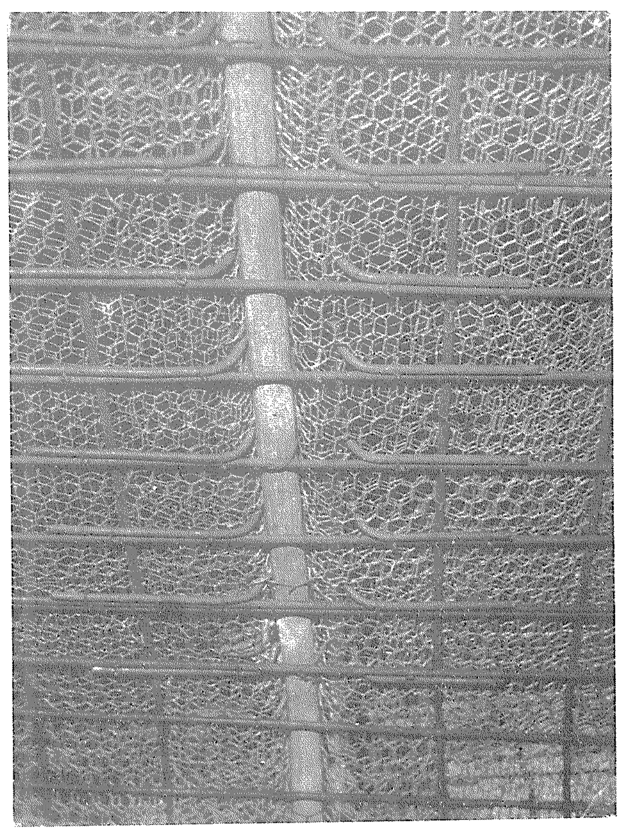


Fig. 25 Bending and tying these rods back in line with the hull.

Fig. 26 Close up of floor reinforcement rods bent and tied in line with the horizontal rods.



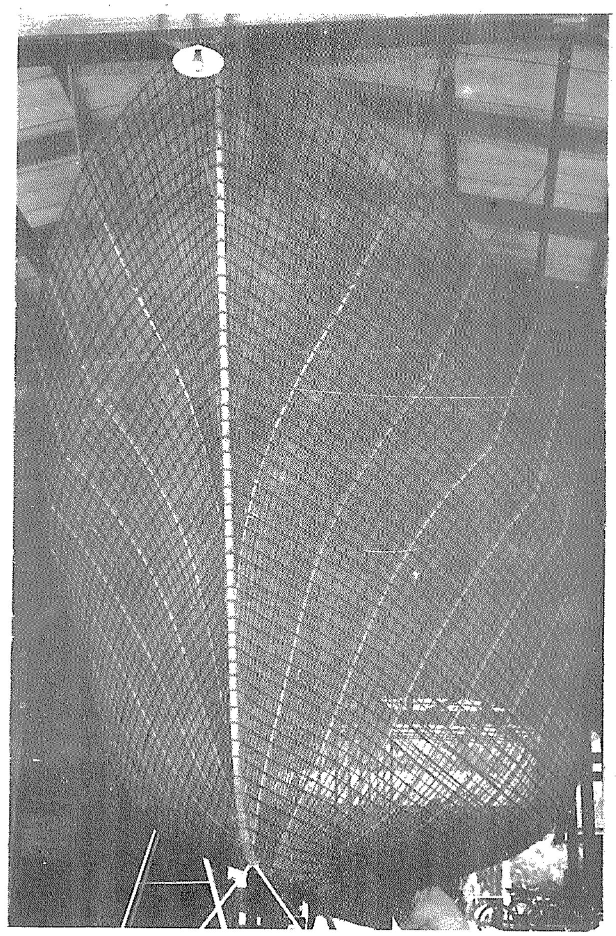


Fig. 27 The hull with all the inner mesh in place.

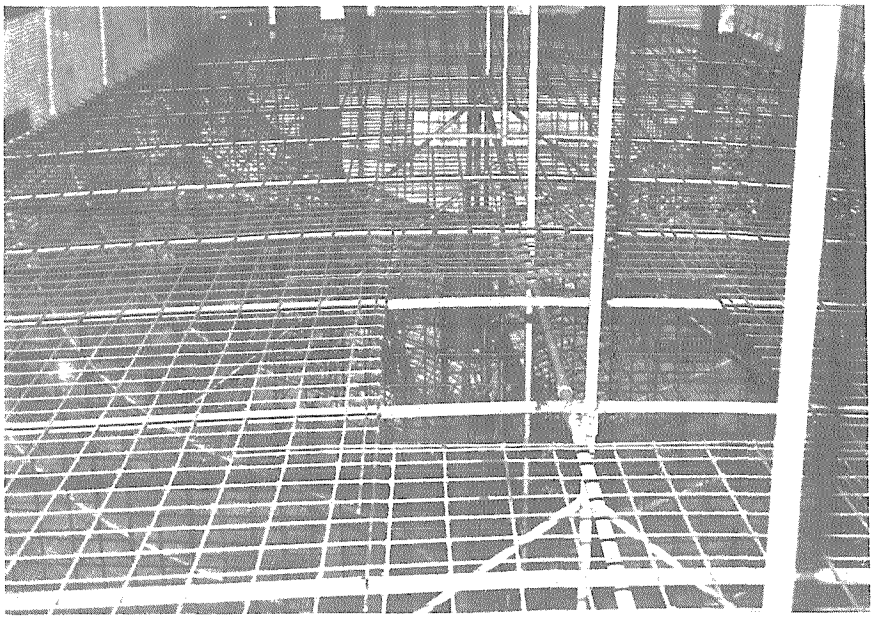


Fig. 28 Laying the deck rods over the pipe beams.

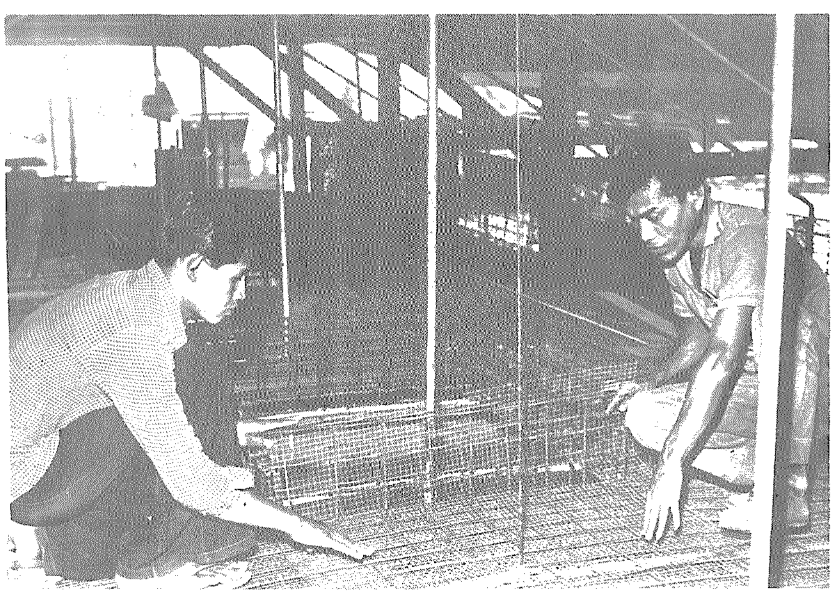


Fig. 29 Placing the mesh on the side of a coaming.

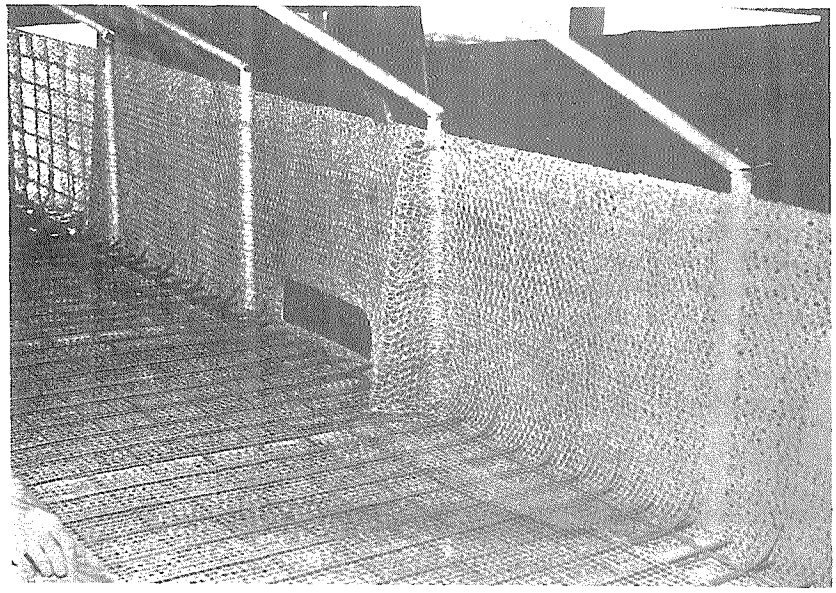


Fig. 30 The bulwarks covered with mesh.

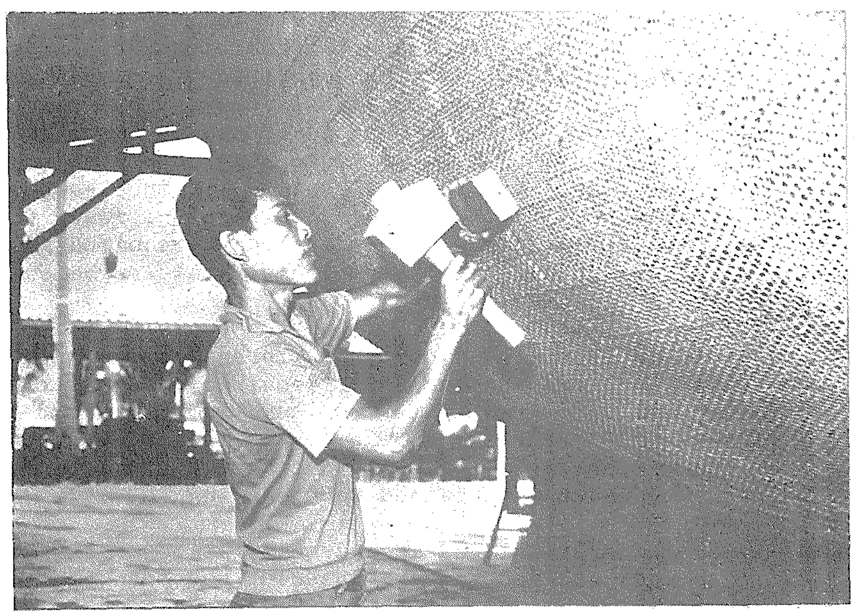


Fig. 31 Hammering the completed hull to smooth out irregularities.

The final tasks in the preparation of the mesh reinforcement consisted of the fixing of the four outer layers of mesh on the hull. These layers were applied longitudinally from the stern forward and from the sheer down; laps being of a minimum of 75 mm (3") but with the layers being allowed to follow the curve of the hull naturally without distortion. Due to changing curvature, this caused the overlap to increase from layer to layer. When this overlap became too great the mesh was cut and repositioned for a further run.

With all mesh in place and tied off against the rods, the whole reinforcing parcel was tied tightly together by wire ties at every reinforcing rod intersection, both on the hull and deck - some 30,000 ties in all. Ties bent in the shape of a U were pushed through the mesh parcel at each intersection by a team of workers, with a second group tying off the ends, cutting off the excess wire and bending the tied ends back neatly into the reinforcing. Great care was taken to avoid protruding ends of wire, as this would have resulted in rusting after plastering, as well as causing damage to the workers' hands during the plastering process.

When this stage was completed the hull was hard, and a blow with a wooden mallet only resulted in the mallet bouncing off the reinforcing without damage. To eliminate the small bumps and hollows caused by the tying of the mesh, the whole hull was smoothed by beating the mesh flat with a wooden block and mallet, as seen in Fig. 31. Note the smooth surface achieved in the area already covered, while bumps and hollows can still be seen in the lower right hand corner, which the workmen have not yet reached.

3.8 Plastering

The mixture used was that decided on as a result of the tests described in Section 2. The sand was sieved before plastering to eliminate larger particles and keep to the grading curve used in the test samples. All mixes were made by weight. As no paddle type mixer was available, mixing was done by hand. The dry ingredients were first weighed and then mixed in a conventional three blade mixer. They were then placed in one of three prepared plastering bays ready for the addition of the water and plasticising additive, which had previously been weighed and mixed together. Three mixing bays were used so that at times when considerable amounts of mortar were required by the plastering crew, three separate mixes could be in progress - one ready mixed and being carried to the plasterers by the carrying team, one being mixed, and one of dry ingredients placed in the bay, after weighing, ready for the mixers. In this way small batches of mortar could be prepared as required and a careful check kept on the correct mixing of all the ingredients. Batches based on 25 kg (55 lbs) of cement were prepared at one time.

The plastering team consisted of three professional plasterers, (all that were available; more would have been desirable if possible), some six workmen with experience of plastering, although not full-time professionals, and a mixing, carrying and mortar placing team of 15 persons. Due to the lack of experience in the group in this type of work it was not felt possible to plaster the whole hull in one day, and a wet or dry epoxy glue had been obtained for jointing.

A bulkhead was first plastered as a demonstration of the method and to familiarize the team with the technique. The keel was then poured, and complete penetration obtained by the use of a pencil vibrator as seen in Fig. 32. Penetration of the mortar through the mesh to the outside of the hull is seen in Fig. 33. The next stage was to vibrate the mortar mixture into the join between deck and hull. Penetration into this radiused area is difficult to achieve by hand, and the vibrator is a very useful tool in such areas. Fig. 34 shows the vibrator being used along the deck line inside the bulwarks, and in Fig. 35 a plasterer is checking for complete penetration, and smoothing off the excess mortar with a wooden float.

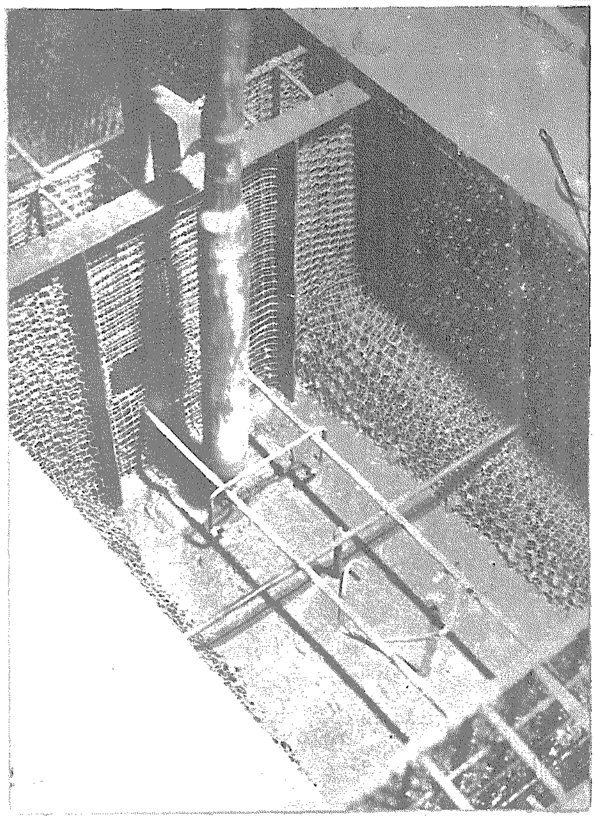


Fig. 32 Vibrating the mortar in the keel area.

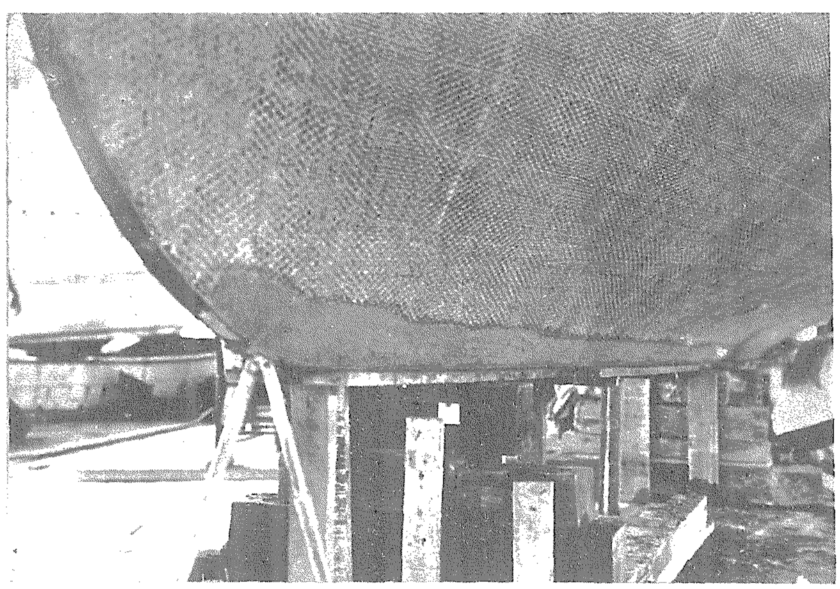


Fig. 33 Complete penetration of the mortar in the keel area.

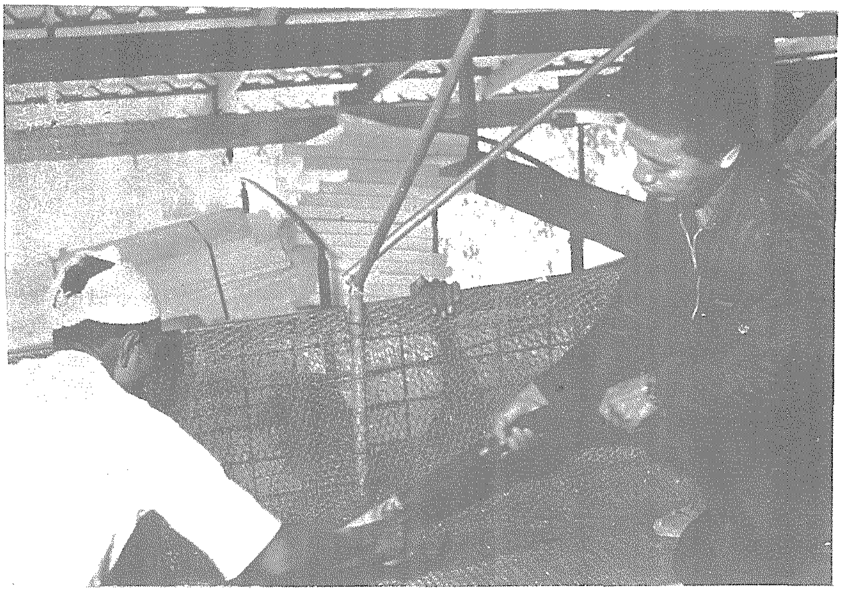


Fig. 34 Using the vibrator to fill the radius of the deck edge.

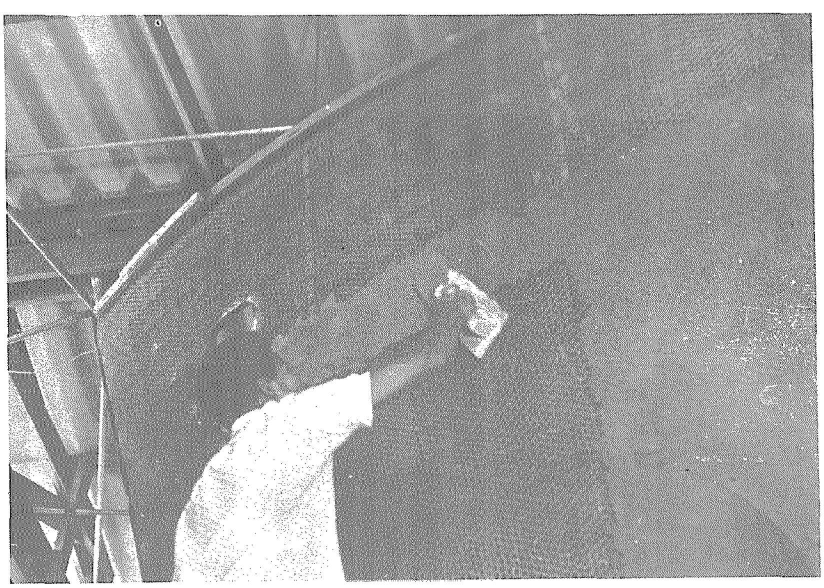


Fig. 35 Smoothing off the excess mortar as it is forced through the mesh by the vibrator.

The vibrator was also used along the pipe frames which were the next area of mesh to be filled, care being taken in all cases not to over-vibrate, causing separation of the mortar. When a section of two frame bays on both sides of the boat had been completed, with full penetration achieved along the deck edge and down the frames, then the team of hand workers followed filling in the mesh between the frames with mortar, applied by a gloved hand, as seen in Fig. 36. Fig. 37 shows the same operation taking place on a bulkhead. A team mate on the opposite side checks the mesh for complete penetration of the mortar and advises the mortar applier where voids exist.

When the mesh has been completely filled, excess mortar is scraped off and the workers move on to the next section. The completed section was left for a period of thirty minutes to one hour before the professional plasterers followed on with wooden float and steel trowel, smoothing out the surface and bringing the mortar cover over the mesh to a final thickness of about 3 mm (1/8"), as seen in Fig. 38.

Supervision of the plastering process by qualified foremen and conscientious work by the plastering team are vital if voids are to be avoided. This is the stage of the construction which requires the greatest degree of skill and supervision as a hull can be ruined by careless work.

It was not possible, with the work force available, to complete the whole hull in one operation, and two vertical joins in the hull were necessary. At the end of one day's work the plasterers finished off to a jointing edge and the next morning a coat of wet to dry epoxy glue was applied to the joint, before continuing with the plastering process. In practice these joints proved perfectly satisfactory and no weeping or spalling off of mortar has occurred.

Decks and bulkheads were plastered in the same manner and hull decks, bulkheads and bulwarks were completed in five working days. With more experience in the method, speed of operations could be increased and this time could probably be reduced to a maximum of three working days.

3.9 Curing and painting

Curing of the hull was controlled by the use of water sprays. The easiest way of doing this is by the use of perforated pipes connected to a water supply but, in this case, water pressure at the fisheries station was inadequate for the use of this method. Spraying was therefore carried out using several portable spray pumps of the type used for the spraying of fruit trees with insecticide. This proved a satisfactory, if rather laborious, method of keeping the hull continually damp.

The completed sections were allowed to set for a period of twelve hours before spraying was begun and continued for a period of fifteen days, by which time the mortar was considered to be sufficiently cured to allow the curing process to continue naturally without risk of shrinkage and consequent cracking. As the hull and deck were plastered in sections, care had to be taken that water from the spraying could not interfere with the setting of the freshly placed mortar. Then as the work proceeded each completed section was, after its twelve hour initial set, included in the spraying until finally the whole hull was being sprayed at twenty to thirty minute intervals a day. Tarpaulins were hung to keep wind and sun from the completed hull during this curing process.

When the curing process was completed a check was made for voids in the shell, which could occur due to faulty plastering techniques. The whole of the hull was sounded by tapping with a light hammer on the mortar and an area containing an air pocket under the surface was easily recognizable. Several voids were found and these were filled by breaking away the thin surface coating, cleaning out dust and particles of broken mortar and then replastering with a mortar to which had been added a vinyl

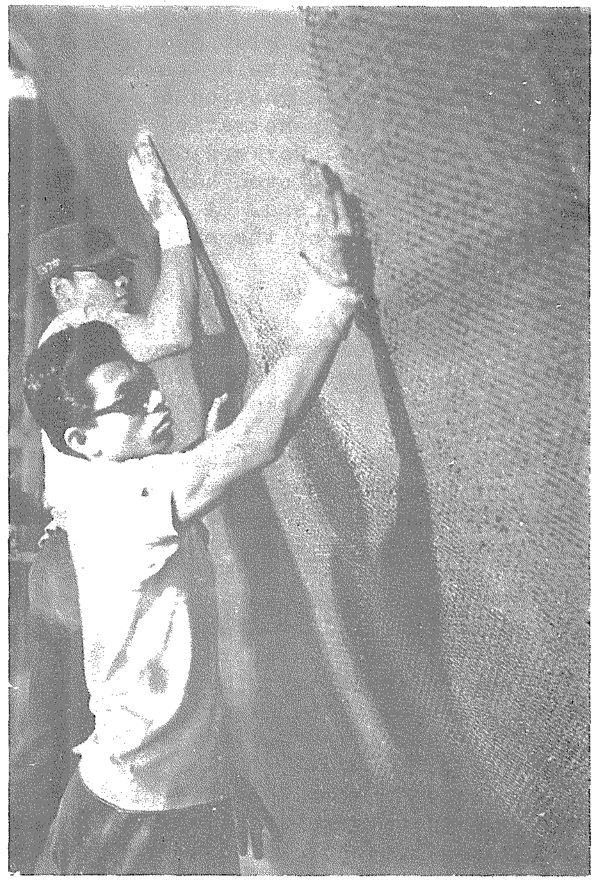


Fig. 36 Forcing mortar through the mesh by hand from the outside.

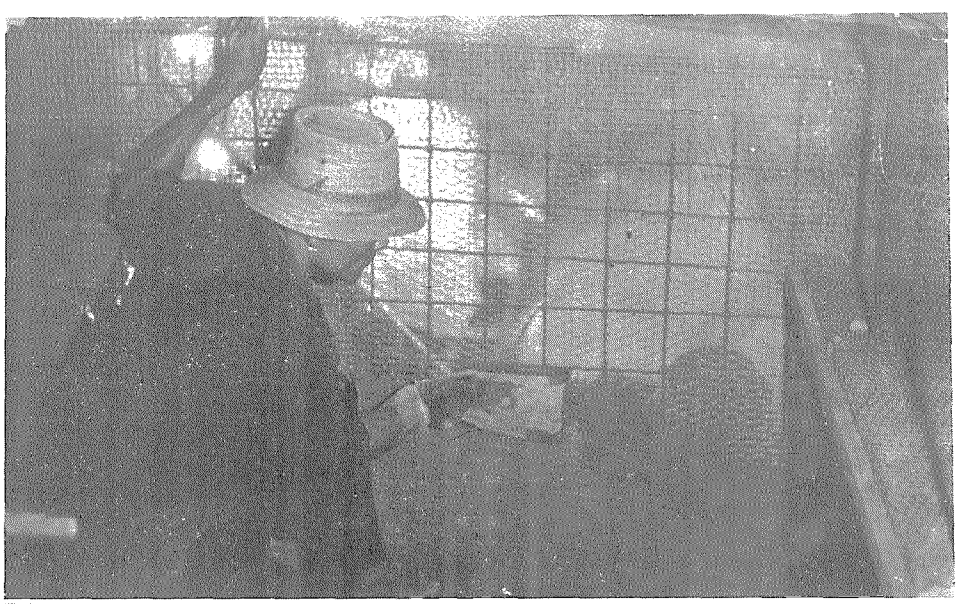


Fig. 37 Plastering a bulkhead

Fig. 38 Smoothing off the exterior of the hull.

Fig. 39 Painting the hull after curing.

polymer bonding agent. In areas where long voids might occur, such as along a stem or keel, it would also be possible to drill holes into the void and pump in a thin grout until the mixture could be seen to have completely penetrated the void.

After the hull was cured a month elapsed before painting was begun, to allow the maximum amount of moisture to escape before sealing the hull. Some rubbing down of minor imperfections was done by hand and a few ties which had been left too close to the surface were dug out and cut back and the holes plugged with epoxy filler, but excessive grinding of the hull was avoided as this would have exposed mesh on the surface with later problems of rusting.

The hull above the waterline was given one coat of clear epoxy priming and then three coats of epoxy gloss paint. The first coat of epoxy paint is seen being applied over the clear primer in Fig. 39. The hull below the waterline was painted with a tar epoxy compound and then given one coat of antifouling. The finished result is seen in Fig. 40. The inside of the bilges was also coated with a diesel-oil resistant tar-epoxy coating to prevent attack of the concrete surfaces by spilt fuel. The inside of the hull was painted with three different coatings by way of experiment: an epoxy based paint, an ordinary oil based marine coating and a white cement of the type used by plasterers.

3.10 Fish hold insulation

Insulation of the fish hold was a relatively simple process. Lengths of 6 mm (1/4") steel rod welded to the reinforcing of hull, deck and bulkheads had been left protruding from the inner surfaces of the fish hold. Sheets of styrofoam were glued to the hull, deck and bulkhead surfaces as seen in Fig. 41, and the protruding lengths of rod used as welding points for a light framework of reinforcing rods. Two layers of mesh were then tied to these rods as seen in Fig. 42 and then the surfaces plastered in the same manner as the hull, see Fig. 43.

The fish hold floor and sides of the shaft tunnel were formed by laying a rough sawn 1/2" wooden flooring on top of the concrete floors, covering this with a vapour barrier of tar paper, then styrofoam and then rods, mesh and plaster. The shaft tunnel top was covered by removable wooden hatches with styrofoam insulation incorporated.

3.11 Engine installation

After curing and before painting the engine was installed in the hull, the bearers had been prepared with 15 mm (5/8") steel bolts embedded in the concrete and 100 x 100 mm (4 x 4") wooden bearers were bolted down on top of the concrete bearers. The purpose of the wooden bearers was to assist in the absorption of engine vibration and simplify the lining up of the engine and shaft.

Fig. 44 shows the engine in position on its bearers. The transverse floors can clearly be seen, as can the longitudinal wooden bearers in the lower foreground. The wooden battens seen bolted to the 2" x 2" angle iron are supports for the movable wooden flooring in the engine room.

3.12 Fitting out

A wide rubbing strake and rail cap were fitted by bolting through the F/C hull. Holes were drilled with masonry drills and bolt holes sealed with grommets of caulking cotton, soaked in caulking compound both on the outside and inside of the hull. As an extra precaution against leakage, the nuts and washers inside the hull were sealed with an epoxy filler and bonding agent.

At this stage the hull was launched, and Figs. 45 and 46 show the launching process and the hull after launching. No leakage or damp spots were found and the bilges remained completely dry.

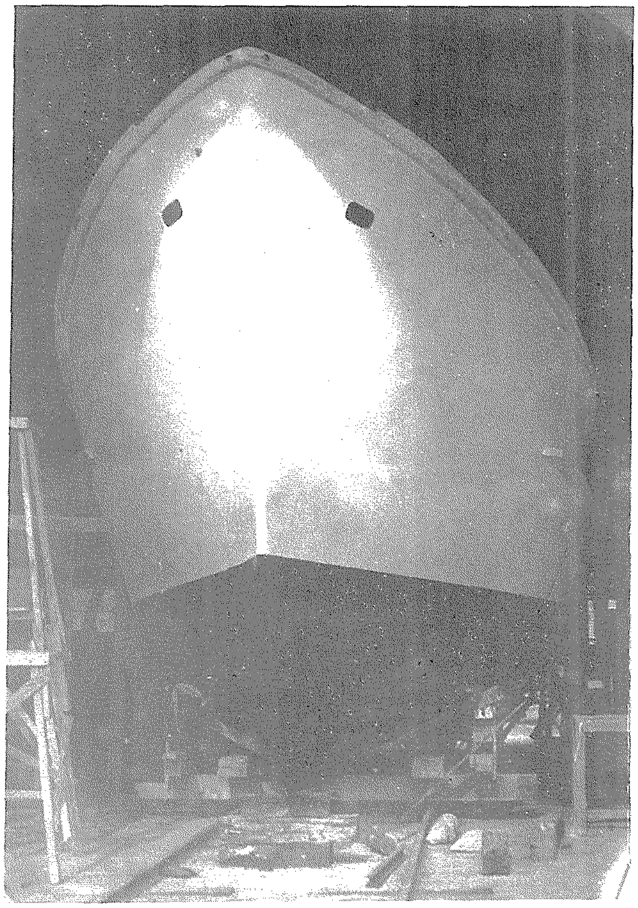


Fig. 40 Painting completed.

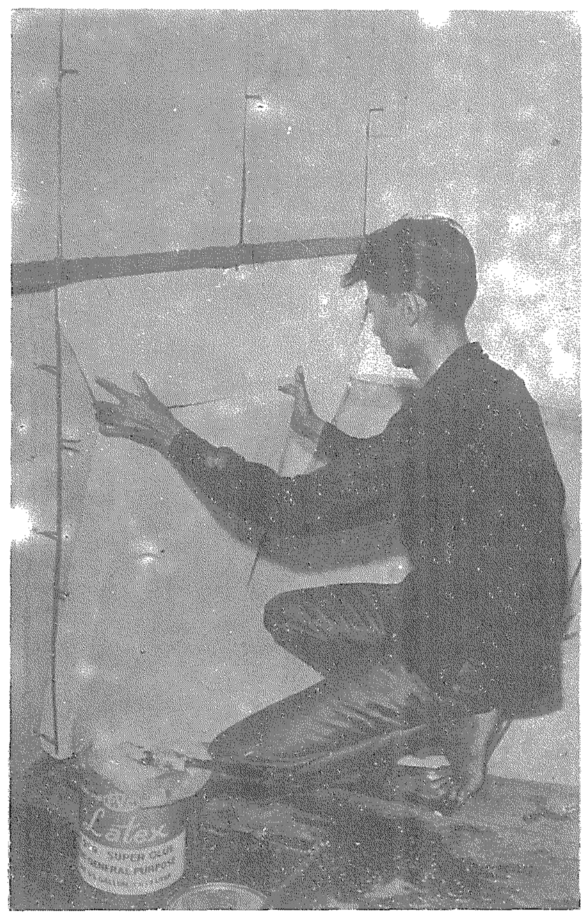


Fig. 41 Styrofoam insulation blocks being glued in the fish hold.

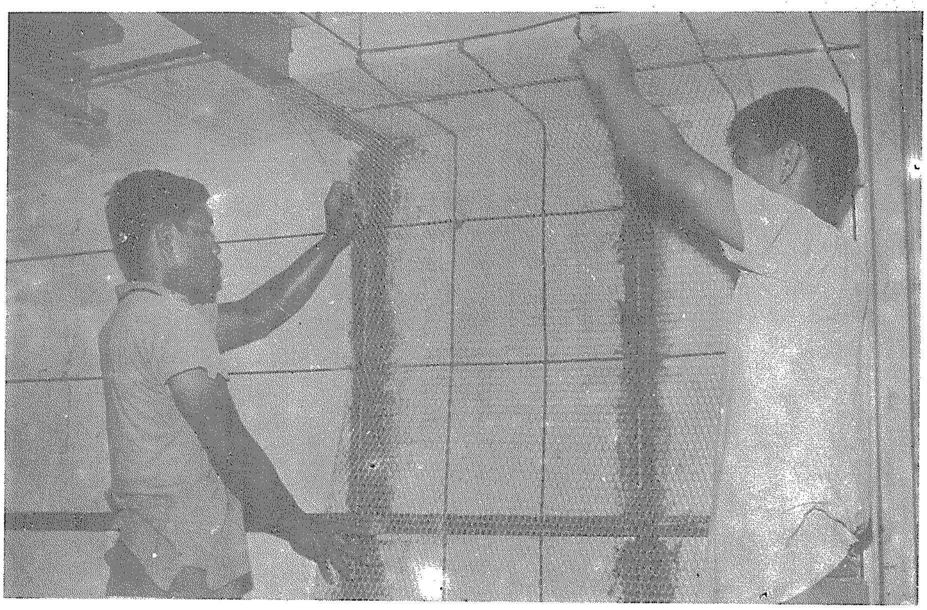


Fig. 42 Mesh covering being applied over the styrofoam.

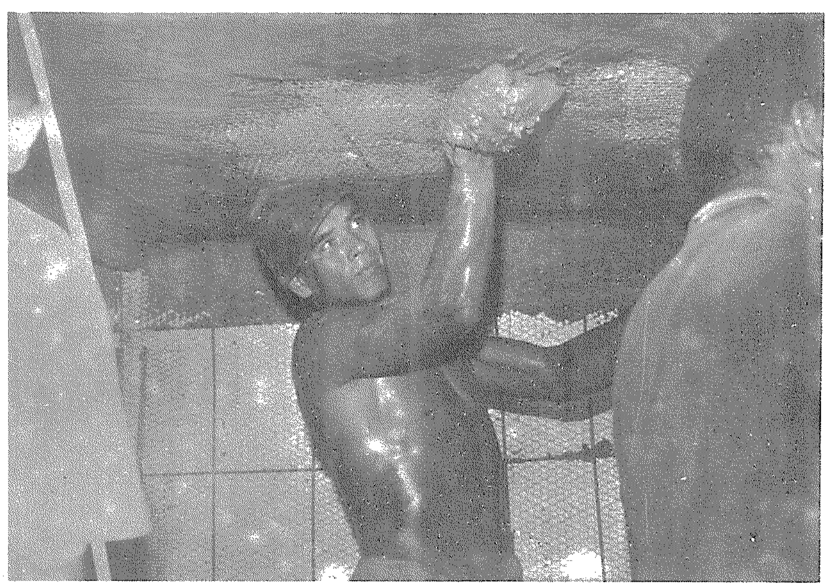


Fig. 43 Plastering the interior of the fish hold.

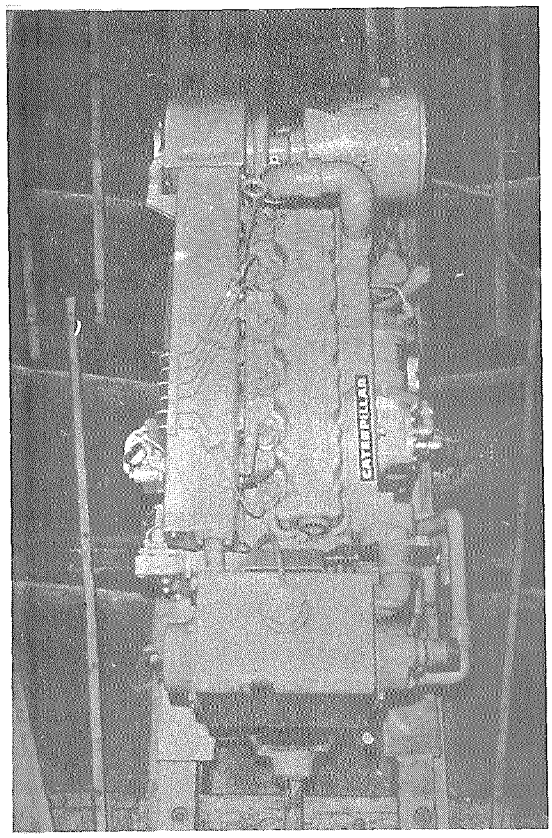


Fig. 44 The engine in place on its bearers.

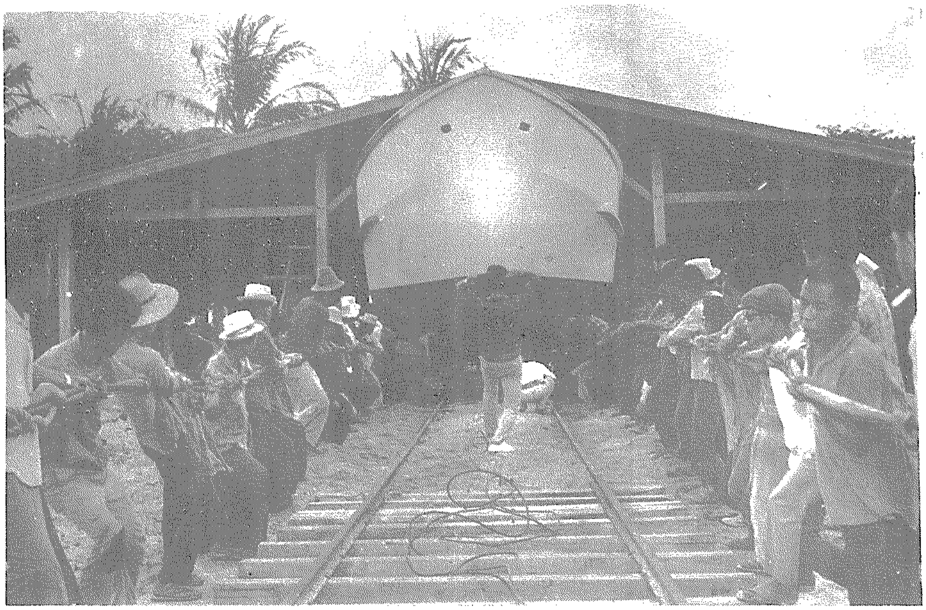


Fig. 45 The launching.

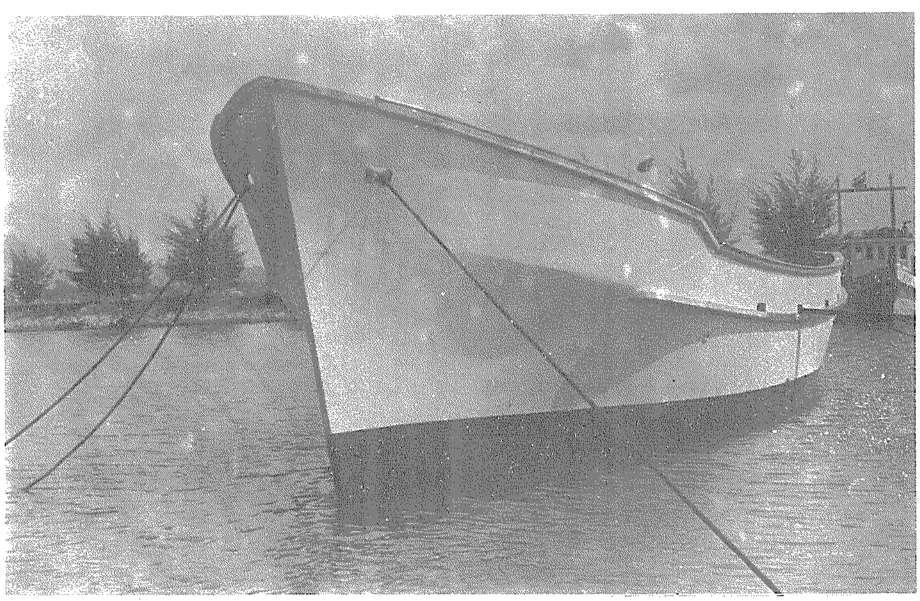


Fig. 46 The hull afloat immediately after launching.

Hatch coamings had been formed of ferro-cement as already described but, again, as a means of comparing one method with another no coaming had been made for the deck house sill. Instead, a wooden sill was bolted directly to the F/C deck with a layer of canvas impregnated with caulking compound between F/C and wood. The wooden deck house was then constructed on this sill in the conventional way. Although this method did prove watertight, it was not felt that any considerable labour saving had been achieved and that in the long run the F/C coaming would prove to be the better solution.

Figs. 47 and 48 show views of the vessel during fitting out. The deck house is completed, the trawl winch installed and the drum for hauling the trawl net is almost completed. Note the stern roller, to aid in the trawl, and the wooden chafing strips bolted to the bulwarks aft between rubbing strake and rail. These are intended to protect the F/C bulwarks from damage by the steel-shod trawl doors as they are being brought aboard.

Fig. 47 shows the off-centre trawl winch, fish hold hatch, mast and foundation for the trawl warp guide blocks which lead the trawl warps from the winch to the foot of the gallows. The winch and guide block foundations are through bolted to connect with the channel iron girders previously placed under the deck. In this way the considerable loads which may occur, for example when the trawl is caught in a fastener, are distributed over a large surface area.

The wooden mast is stepped in a steel foundation bolted to the deck, compression loads being taken by the engine room bulkhead and the forward pair of fish hold stanchions.

In Fig. 49 the vessel has taken the ground at low water, and a general view of the hull and superstructure can be seen. Later additions included trawl gallows, trawl blocks, boom and support and all the minor details of fitting out which go to complete a fishing vessel. Because of the risk of impact damage to the hull from steel shod trawl doors, the trawl gallows were specially designed to be extended overside during fishing operations, but retracted in port to avoid damage when alongside other vessels. Fig. 50 shows one of the gallows in the retracted position, while in Fig. 51 it has been pivoted overside. In the latter position the door can be brought up clear of the hull to the rubbing strake, and the chafing strips from rubbing strake to rail prevent damage above this point.

3.13 Hull repairs

During the final fitting out for trials, the vessel was lying at anchor when an accident occurred, which gave an opportunity to demonstrate the ease of repair of a ferro-cement hull. During a manoeuver at night, an 18 m wooden fishing vessel going astern to clear a dock struck the forward section of the vessel with considerable force. The point of impact was about 0.6 m (2 ft) aft of the bow and about 0.75 m (2.5 ft) above the waterline. The damage seen in Fig. 52 was caused by the transom corner of the heavy wooden rubbing strake used on this type of vessel and, as can be seen, the impact caused an indentation in the surface of about 230 mm (9") long by 5-7 cm (2-2 ½") wide and about 9 mm (3/8") deep. Some spalling of the interior mortar also occurred as seen in Fig. 53, but the only evidence of damage in the region of the internal layers of wire mesh were two fine hair cracks, which, if the accident had occurred below the waterline, might have allowed a slight seepage of water into the hull; but nothing serious and well within the capacity of the average bilge pump.

Repair took a total time of two hours for one man and consisted, as shown in Figs. 54 and 55, of chipping away the damaged mortar with hammer and cold chisel, bending the mesh back into place, clearing dust and debris from the area and replastering with a special quick setting underwater cement, patching and bonding compound. The same result could also have been achieved with ordinary mortar and a wet to dry epoxy adhesive to ensure a good bond.

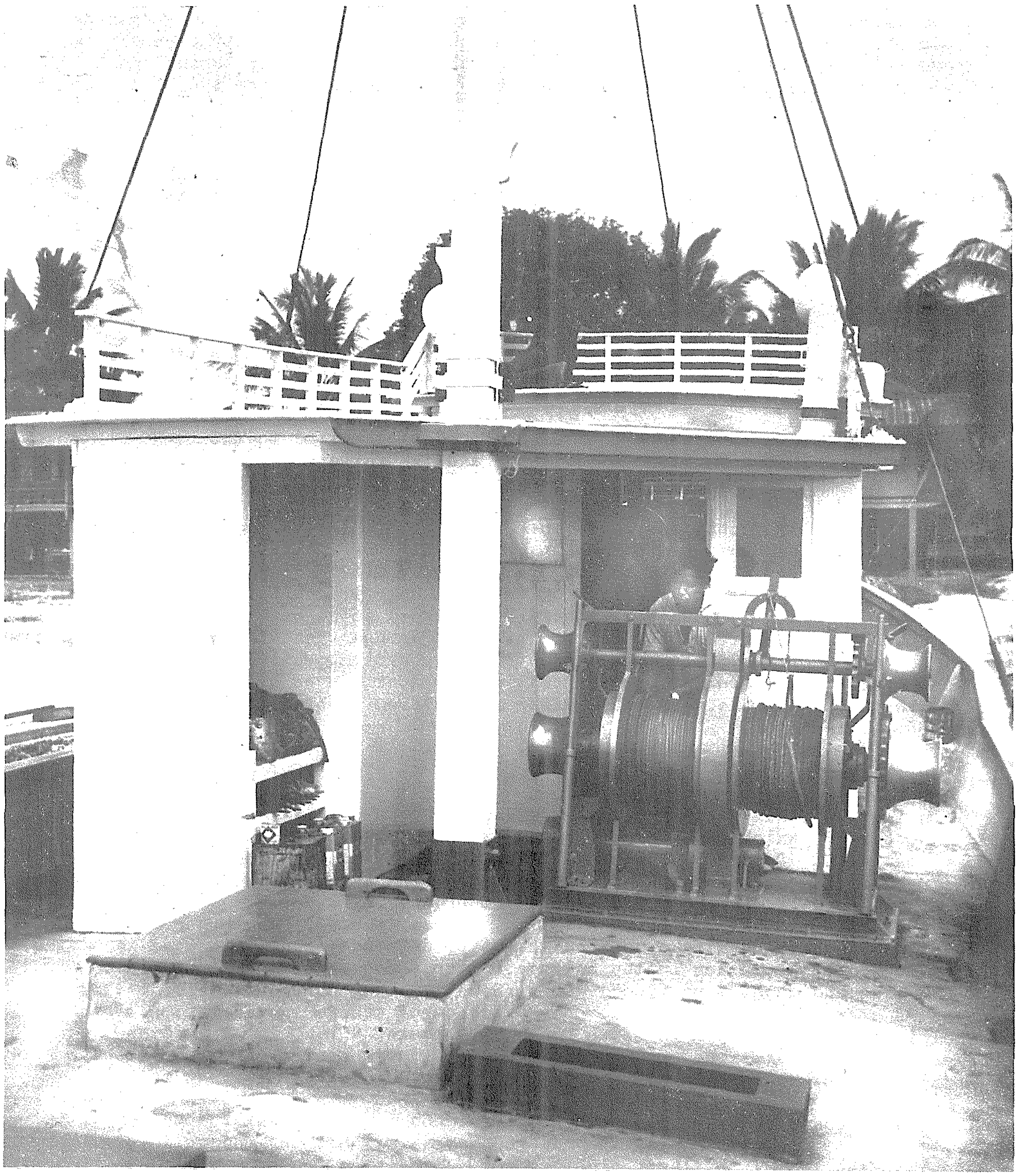


Fig. 47 Fitting out. The installation of the trawl winch.

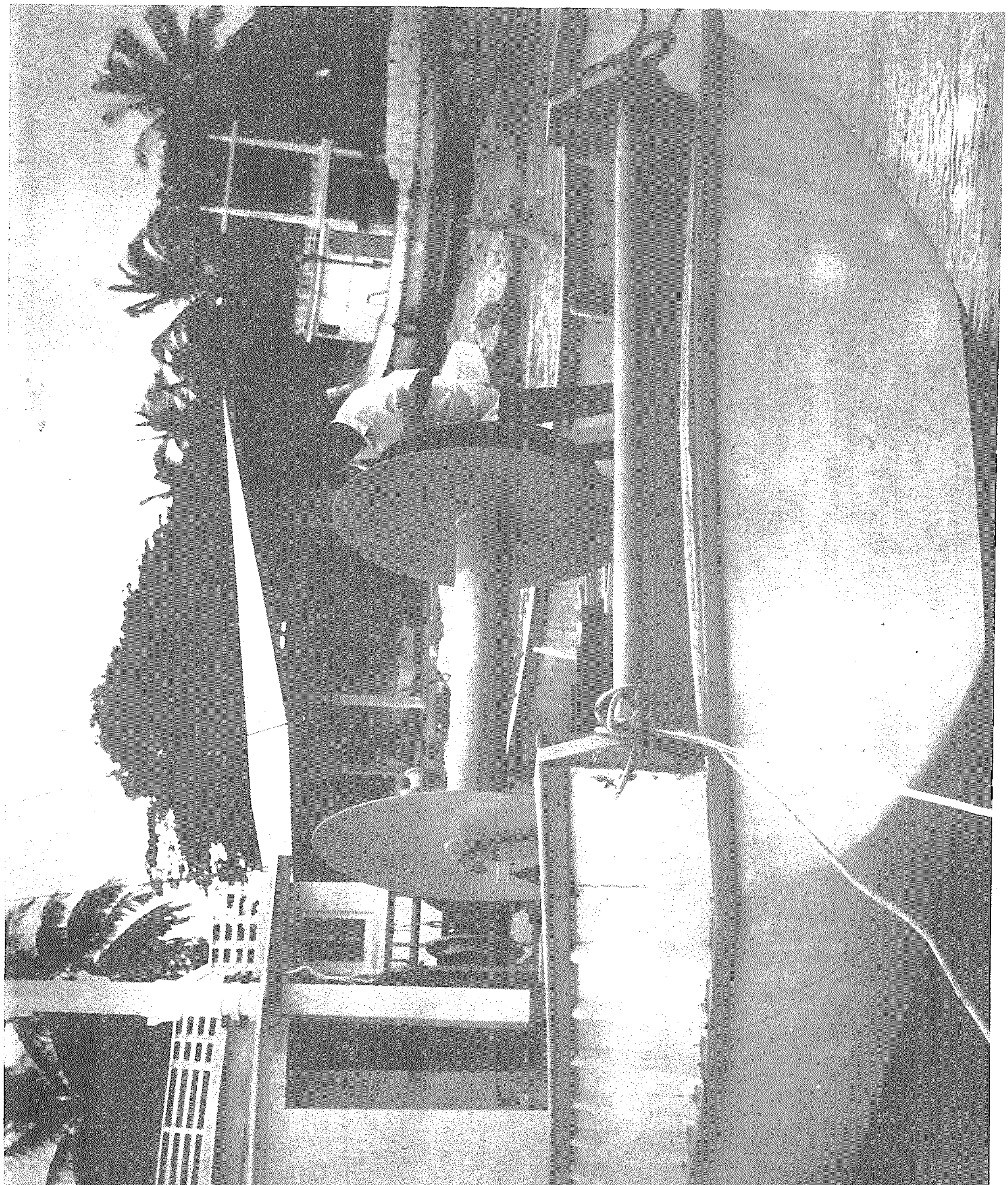


Fig. 48 Fitting out. The trawl drum and stern roller in place.

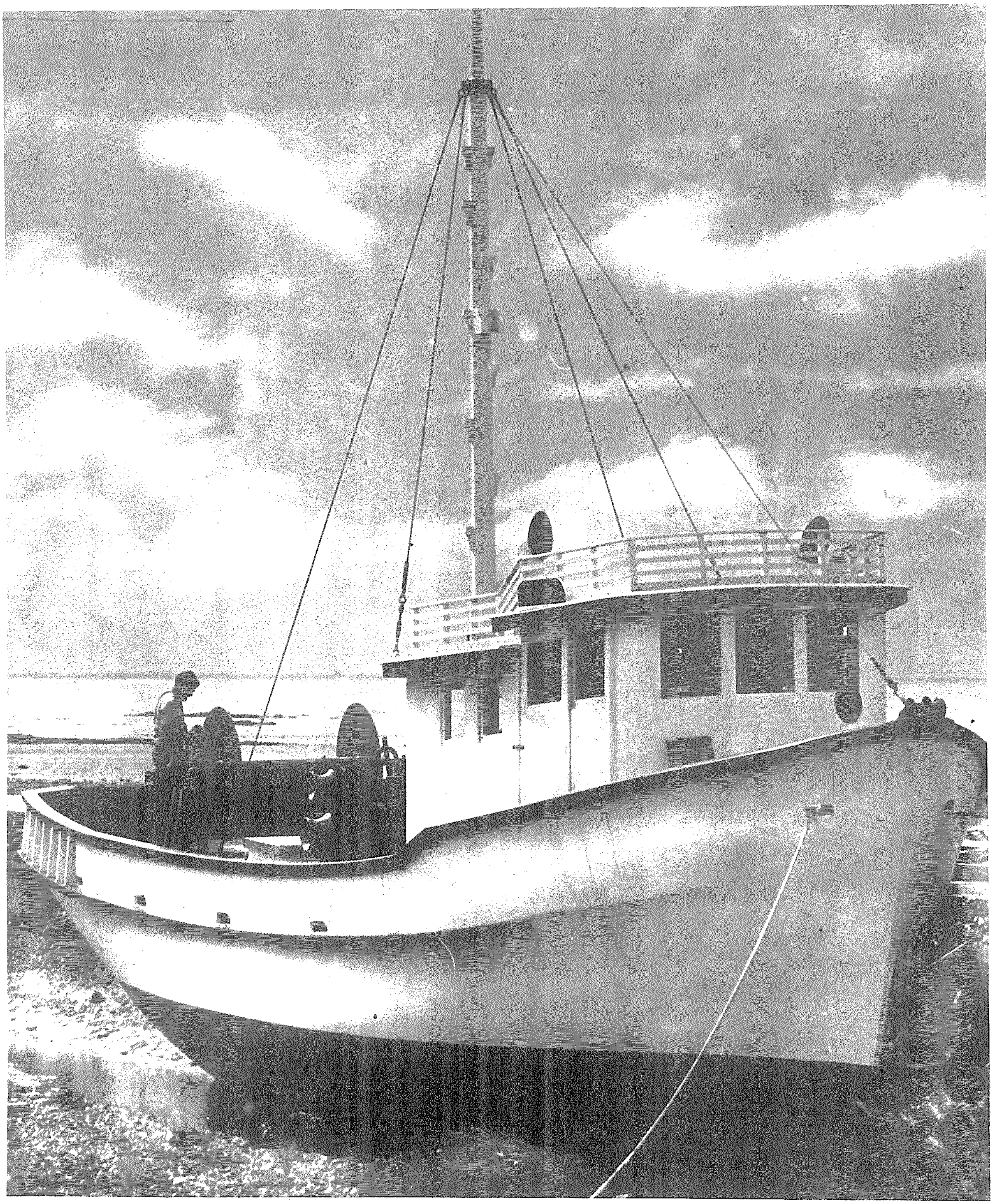


Fig. 49 The completed vessel before the trawl gallows are fitted.

Fig. 50 Trawl gallows in the retracted position.

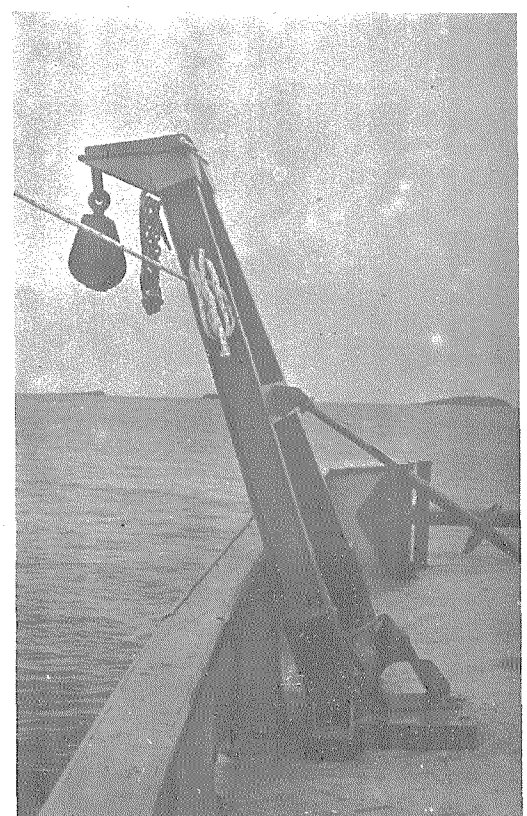


Fig. 51 Gallows extended outboard to the operating position.

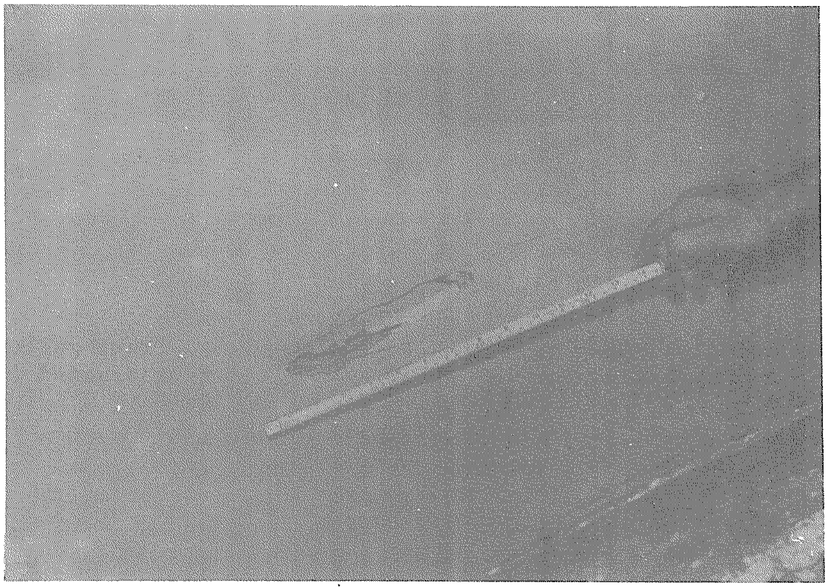


Fig. 52 Hull damage caused by collision.

Fig. 53 Interior view of same damage.

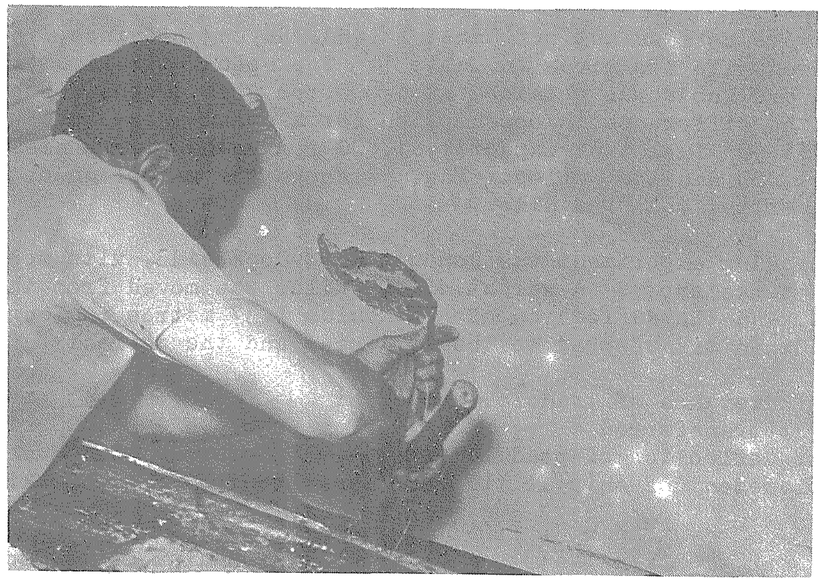


Fig. 54 Cleaning away damaged mortar from the mesh.

Fig. 55 Replastering. Total repair time less than 2 hours.

4. TRIALS

Trials were carried out off Samet island, Rayong Province, and results of runs over the measured mile are given in Table 1. Top speed at maximum rpm of 2,000 was 9.2 knots, and 8.8 knots was obtained at 1,800 rpm with a considerable saving in fuel consumption - the difference in consumption for a speed increase of 0.4 knots being 12.8 litres! At 90% fuel tank capacity, 1,800 rpm would give a steaming range of approximately 1,000 nautical miles. Fig. 56 shows the vessel under way during a run at 1,800 rpm over the measured mile.

The inclining experiment was conducted at dock side, with mooring lines slackened, and tanks empty. A weight of 800 kilos was moved from the ℄ to the starboard side, and the deflection of a pendulum 1.37 metres in length was measured. The weight was then transferred to the port side and the deflection was again measured.

Total distance of transfer of weight	= d =	4.45 metres
Weight transferred	= W =	800 kilos
Total deflection of pendulum	=	0.19 metres
Displacement of ship at time of measurement	=	37,000 kilos = $\triangle$

$$GM_o = \frac{W \times d}{\triangle \times \tan\theta} = \frac{W \times d}{\triangle \times \frac{\text{pendulum deflection}}{\text{length of pendulum}}}$$

where θ = angle of deflection

$$GM_o \text{ (measured)} = \frac{800 \times 4.45}{37{,}000 \times \frac{0.19}{1.37}} - 0.693 \text{ metres}$$

GM (calculated) - 0.72 metres

The period of roll was measured at anchor in a cross swell. Ten consecutive rolls were measured and the result averaged to give a rolling period of 4.8 Secs. The relationship between roll period and the moment of inertia of the ship, and the water moving with it, can be written as

$$GM = \left(\frac{2\pi . K}{\sqrt{g}.Tr}\right)^2$$

In the metric system:

$$GM = \left(\frac{k.B}{Tr}\right)^2$$

From GM_o = 0.69 metres taken from the inclining experiment k = 0.88.

In the foot system:

$$GM = \left(\frac{1.108 \ m.B}{Tr}\right)^2$$

which gives the m value 0.44.

(B is the Beam of the vessel)

Trials of the fishing gear were also carried out further offshore in winds of force 4, with a westerly swell and wave height of about 1.5 m (5 ft). Fig. 57 shows the use of the trawl drum for taking in the trawl net. The doors were hauled up to the gallows and secured in the usual way. Strops fastened to the trawl drum were then clipped to the bridles with the aid of G links. The warps were then slackened until the weight of the trawl was taken on the drum. With the rope drive from the port warping head of the trawl winch powering the drum, the strops were hauled in until the

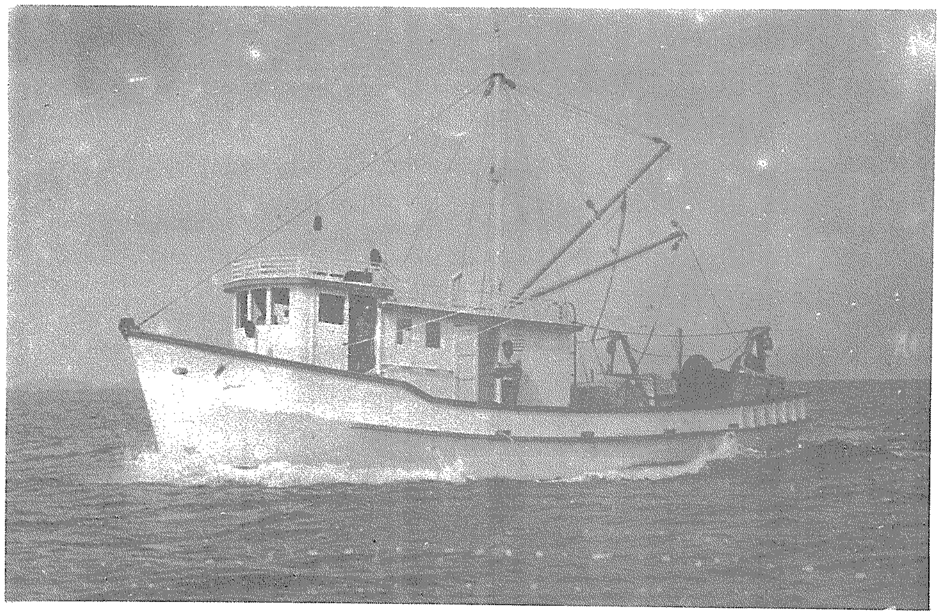


Fig. 56 On trial run at 1,800 rpm.

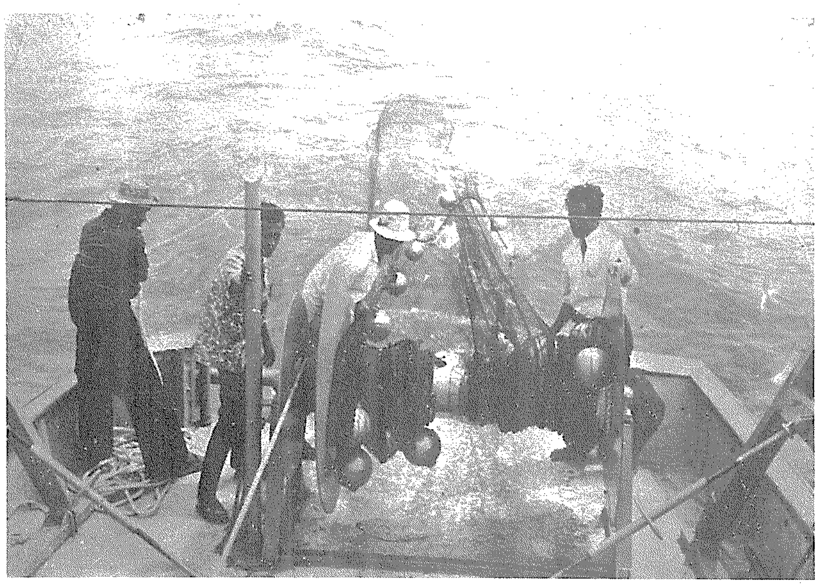


Fig. 57 The net being rolled on the drum.

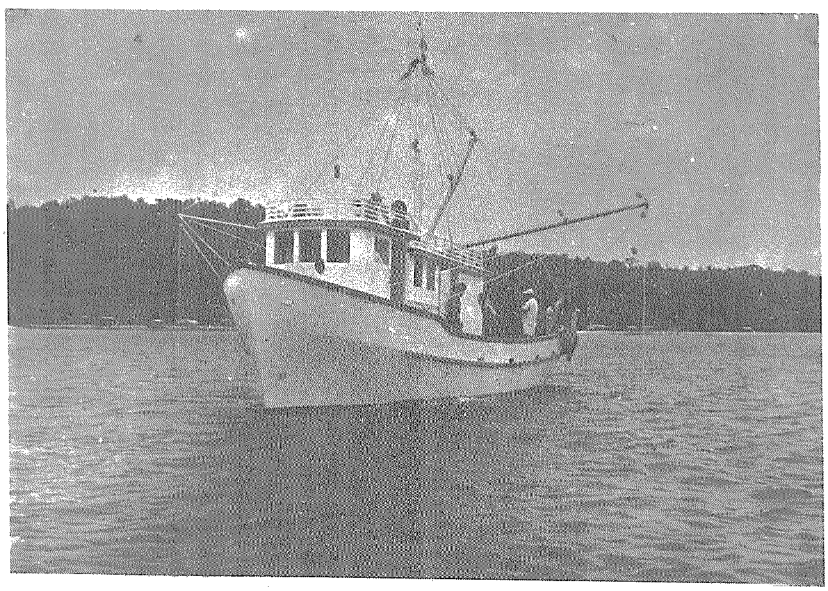


Fig. 58 Stabilizer gear in working position.

Table 1

TRIAL DATA

Vessel: 16-m Ferro-cement trawler Date: 31/7/69
Displacement: 37 metric tons Trim: 7 cms aft at WL5
Course: Measured nautical mile, bearing 119° - 299° true.

Weather Conditions: Wind - West F.3-4
Maximum Ambient Temp. 90°F Sea - Slight west
Barometric Pressure: 29.5 Current: SE about 1 knot

Run No.	Time		Engine rpm	Vessel Speed (kn)	Average over 2 runs	Intake Manifold Press. in Hg. w/Load	Exhaust Back Press. Inches Water		Fuel Rate (1/h)	Engine Oil Press.	Gear Oil Press.	Engine Water Temp. (°F)	Remarks
	Min	S					No Load	With Load					
1	10	46	1000	5.57	6.0	29	0.6	1.5	8	60	225	145	
2	9	26.5	1000	6.36						"	"	"	
3	10	27	1200	5.74	6.5	29.5	1.0	2.0	10	"	"	"	
4	8	11	1200	7.33						"	"	"	
5	8	52.5	1400	6.77	7.5	30.8	1.2	2.5	14.7	"	"	"	
6	7	20	1400	8.18						"	"	"	
7	7	58	1600	7.53	8.2	34.5	1.4	3.0	21	"	"	"	
8	6	46.5	1600	8.86						"	"	"	
9	7	3.5	1800	8.49	8.8	40	1.9	4.6	32.4	"	"	"	
10	6	32	1800	9.18						"	"	"	
11	6	45	2000	8.89	9.2	48	2.3	5.5	45.2	"	"	150	
12	6	20	2000	9.47						"	"	"	
13	6	44	2000	8.91	9.2					"	"	"	
14	6	23	2000	9.40						"	"	"	
15	9	58.5	1200	6.02	5.8								with plate
16	10	45	1200	5.58									stabilizers
17	7	14.5	1800	8.29	8.2								" "
18	7	21	1800	8.16									"

trawl warp could be unclipped by the aid of their G links. The bridles were then spooled onto the drum, and hauling continued to bring the main body of the net up over the stern roller and on to the drum, with two men in the stern helping to spool the net evenly. With the main body of the net on the drum, sufficient slack was left in the water to enable the cod end to be brought around to the starboard side, where it was lifted aboard with the aid of the main boom.

All Thai fishing boats are fitted with large bilge keels and this, combined with the narrow beam and low stability, tends to give a very slow period of roll. It was felt that, for conditions of safety in operation, the stability of the F/C vessel should be considerably higher than that normally found on the traditional fishing vessels. In fact, the statical stability found from the inclining experiment does fulfil the Rahola Criterium for stability. However, because of the greater stability (and hence greater safety), the period of roll during the trials was quicker and due to the easy curves given to the bilge radius, for reasons already mentioned above, the amplitude of roll was also greater. The possibility of fitting bilge keels had been considered during the design stage, but due to the experimental nature of this vessel, and the frequent damage to bilge keels suffered by Thai fishing vessels, it was decided not to fit them to this prototype hull. Instead, plate stabilizers of the type used by Pacific West Coast shrimp trawlers were constructed. The booms used to suspend the stabilizers were adapted for the purpose from a pair of steel shrimp trawl booms, and the rig can be seen with the stabilizers in the water in Fig. 58.

The reduction in amplitude of roll when the stabilizers were in use was considerable and estimated to be about 50% of the greatest amplitude, when averaged over a series of consecutive rolls. The stabilizers were also towed over the measured mile (in calm water) to measure the decrease in speed likely to be expected. The results are shown in Table 1, and indicate that, at an rpm of 1,200, the free running speed of 6.5 knots was reduced by 0.7 knots, or approximately 10%. At an rpm of 1,800 the reduction of speed was 0.6 knots on 8.8 knots, or 6.8%. In rough water the percentage loss of speed is likely to be even less when using the stabilizers, because the loss of speed due to rolling has also to be taken into account. Speed losses due to bilge keels are probably comparable, and it would be most interesting to have comparative tests made with two identical boats, one with bilge keels and one with stabilizers.

Trial results of the stabilizers were most successful, and even better results could be obtained using lighter booms specially designed for the purpose. The heels of such booms could be pivoted at deck level outside the bulwarks, thus lowering the centre of gravity of the extra gear and reducing even further the amount of roll.

From the results of the trials the following conclusions can be drawn:

1. The speed achieved by the vessel was satisfactory and compared most favourably with equivalent Thai fishing vessels. The stern wave was not large and economical running at 8.8 knots was achieved at 1,800 rpm.
2. Manoeuvrability trials showed that the vessel was easily handled.
3. Some improvement in performance could be expected by small changes in hull shape, a harder turn to the bilge would help in the reduction of roll and more flare in the topsides forward would increase the buoyancy and reduce pitching.
4. Plate stabilizers are a very effective method of reducing rolling in a cross sea and the loss of speed due to the stabilizers is not excessive.
5. Trials of the fishing gear indicated that the vessel could be operated with a small crew, contact being easily maintained between wheel, winch and working deck. The rope driven trawl drum functioned well and considerable reduction in labour could be achieved by its use. Crews would of course need to be trained in the method to obtain the maximum benefit.

5. COST ANALYSIS

The normal practice in fishing boat construction in Thailand is for the builder to quote a price for the construction of hull, deck, fish hold insulation, superstructure, mast and rigging. The owner then completes purchase of engine and accessories, fishing gear and deck equipment and either arranges installation himself, by a separate contractor or by the builder, who then makes an additional quotation for this work.

In order to provide comparison between a local wooden fishing boat and ferro-cement construction, the cost analysis is arranged in this way, with cost, less profit, given in sub-total A, under 5.1. To compare with costs in other parts of the world, labour overheads and profit percentages are added. Profits and overheads in Thailand are not normally calculated in this manner and allowance for local practice should be made when making a direct comparison.

5.1 Major items and their costs

Item	Cost in Baht (US dollars in brackets)	Total
Materials		
Hull, deck, fish hold insulation, wooden rubbing strakes and rail caps	40,170 (1,931)	
Wooden deck house, mast, boom and rigging	15,660 (750)	
Paint, sealing and bonding materials incl. epoxy enamel and primer, sealing and bonding compounds, tar-epoxy underwater coating, antifouling	9,150 (440)	
Labour		
Labour costs for above items	59,340 (2,853)	
Sub total A, complete hull excl. overheads and profit	124,320 (5,977)	
Labour and yard overheads at, say, 75% of labour cost	44,500 (2,140)	
Yard profit at, say, 15%	25,320 (1,217)	
Sub total B, hull cost with overheads and profit		194,140 (9,334)

Item	Cost in Baht (US dollars in brackets)	Total
	c/f	194,140 (9,334)
Powering of vessel and equipment		
Engine + accessories, incl. alternator and batteries	210,000 (10,096)	
Engine installation incl. stern gear, fuel tanks, steering controls, etc.	23,600 (1,135)	
Electrical installation, wiring	1,940 (93)	
Deck fittings, winch, gallows, trawl drum etc.	68,500 (3,293)	
Gen. equipment, incl. anchors, warps, bedding, etc.	3,900 (140)	
Sub total C, cost of powering and equipping the vessel		307,940 (14,757)
Total cost of vessel equipped and ready for sea, excl. nets and trawl warps		502,080 (24,091)

5.2 Detailed analysis of material quantities and costs

Quantities of materials used are given as a guide for the preparation of estimates. Cost of materials in Thailand is included but should not be used in costing in other countries, because of possible variation in prices.

Material	Quantities	Cost in Baht (20.8 Bt. = 1US$)
Steel reinforcement		
Galvanized hexagonal wire mesh 19 gauge	38 rolls 45 x 0.9 m	
Galvanized square welded mesh 19 gauge	10 rolls 45 x 0.9 m	16,750
1/4" mild steel rod to SS41	5,350 m	3,730
18 gauge soft iron tie wire	200 kg	870
Angle iron 1 ½" x 1 ½" x 3/16"	72 m	456
Channel iron 4" x 2" x 7.09 3" x 1 ½" x 4.60	24 m 12 m	1,152
3/4" ID steel pipe for framing and supporting	500 m	3,200
1 ¼ ID steel pipe for keel and stem	25 m	600
Steel for rudder skeg	1.20 x 30 x 12 mm	600
Welding costs		3,010

Material	Quantities	Cost in Baht (20.8 Bt. = 1US$)
Mortar		
Cement Portland type 11	7 tons	3,500
Sand	8 m^3	400
Plasticising additive, Plastet No.2.	35 litres	2,500
Bonding agent for jointing	1 gallon	495
Paint, bonding agents, etc.		
Epoxy semi-gloss enamel with undercoat	60 litres	3,600
Tar-epoxy	32 litres	2,250
Thinners	20 litres	400
Antifouling	10 litres	1,350
Oil based paint for woodwork	10 litres	1,656
Epoxy glue	2 kg	700
Fish hold insulation		
Styrofoam 4' x 2' x 2" 4' x 2' x 3"	35 sheets 42 sheets	2,280
Latex glue for bonding foam to F/C	2 gallons	627
Wood		
Rubbing strakes, rail caps, deckhouse, construction, mast, interior joinery, etc.	4.19 m^3	9,620
Plywood for lining of deckhouse 8' x 4' x 6 mm	10 sheets	920
Rigging		
Steel pipe for boom	6 m, diam 4"	540
Wire rope for stays	50 m, diam 3/8"	172
Rigging screws, shackles, etc.	5 - diam $\frac{1}{2}$ "	215
Miscellaneous items		
Window glass	2 m^2 of 6 mm thickness	450
Window and door fittings	various	259
Canvas for covering house top	20 m^2 10 oz weight	725
Fastenings, including bolts of various sizes, wood screws and nails	various	2,760

Notes

1. The quantity of cement used was greater than anticipated. Considerable wastage occurred, but it was felt that this could be much reduced as the workers acquired experience of working in F/C.

2. The paint used was mainly epoxy. This was chosen for its good bonding properties with concrete. However, if it is desired to reduce costs, experience in other countries has shown that ordinary marine paints can also be used successfully.

3. No attempt has been made to itemize costs and materials for engine installation and deck equipment, as these vary considerably from boat to boat and with type of engine chosen.

5.3 Cost estimating

Due to the homogenous construction of a ferro-cement hull, the best method of cost estimation is to base on a measure of surface area, (cubic feet in the foot system or cubic metres in the metric system). By estimating the quantities of material necessary for one square metre (foot) of surface, plus the amount of labour needed to produce a similar surface, a fairly accurate approximation of the cost of a range of hull sizes can be found.

Fairly early in the design stage of a new hull it is possible to make an estimation of the surface area of hull and deck. From this can be derived the cost of construction of the complete hull. Cost of engine installation, deck equipment, etc., being basically the same, regardless of hull material, it is then possible from cost data to arrive at an accurate estimate of the cost of the fully equipped vessel.

The total material cost of hull, deck and fish hold of the 16 metre F/C vessel from Section 5.1 is 49,330 Baht. The surface area of hull, bulkheads and deck is 180 m^2 (1,938 ft^2). Therefore:

Material cost per m^2 = 274 Baht ($13.18)
Material cost per ft^2 = 23.7 Baht ($1.14)

The total man hours of labour required to complete a hull of this size is estimated at 4,000. This estimate is based on the experience obtained in the construction of the prototype, allowance being made for increased time due to lack of experience of the work force in this type of construction, and also to the fact that labour was provided by the staff of the fisheries station when they could be spared from normal day-to-day work. Much more efficient utilization of labour could be expected in a commercial boatyard geared to this type of construction.

For a construction time of 4,000 man hours and a total surface area of 180 m^2:

Construction time per m^2 = 22.2 man hours
Construction time per ft^2 = 2.06 man hours

These cost figures apply only to the cost of the ferro-cement hull and fish hold and do not include the cost of wooden deckhouse, mast and rigging, which would need to be applied at standard rates to arrive at the cost of the basic fishing boat hull as quoted by a Thai boat builder.

As an example of comparative costs, it is not sufficiently accurate to compare the cost of the 16 metre F/C stern trawler with the cost of a traditional Thai fishing vessel of the same length in wood. Due to differences in beam and depth the cubic capacity will vary considerably. One way to make a comparison of costs at varying boat sizes is by calculating the cubic number of each vessel and adjusting costs accordingly. However, a more accurate method in this case is to obtain the square meterage of hull and deck surface area and apply the unit costs calculated above.

Taking the 18 metre traditional trawler, hull surface area, including bulkheads, is 97.3 sq metres. Deck area, minus openings, is 40.7 sq metres. Therefore, the

total area of hull and deck = 138 sq metres. As can be seen, then, due to the appreciably narrower beam and smaller depth of the traditional vessel, the total hull and deck surface area of an 18 metre LOA traditional trawler will be less than that of the 16 metre F/C trawler.

Calculating the hull cost on this basis:

Cost of materials = 138 x 274	= 37,800 Baht
Total labour = 138 x 22.2	= 3,060 man hours
Total labour cost at an average of 5 Bt per hour	= 15,300
Yard overhead at 75% of labour	= 11,450
Profit at 15%	= 9,680

Total, hull and deck 74,830

Additional items to be added to arrive at the standard hull price normally quoted have been taken from actual prices quoted by local builders and include materials, labour and profit.

Deckhouse	13,000
Mast + fittings	1,780
Rudder, stock and tube	1,500
Total to be compared with standard hull	91,110

A standard traditional hull cost is generally quoted by the builder as a price per metre length (LOA). Prices range from 5,500 Baht per metre in Rayong, the cheapest building area in Thailand to 6,000 or 6,500 Baht in some of the other centres. This gives a price range for a traditional 18 metre LOA vessel of between 99,000 and 117,000 Baht, and these prices are rising due to the increasing scarcity, and hence higher cost, of good boatbuilding timber. Based on these figures it is possible to quote an equivalent F/C hull as between 9 and 22% cheaper than its wooden counterpart.

These figures only apply of course to Thailand, but by using the material quantities given in Section 5.2 at local prices, it is then possible to arrive at a material cost per square metre (or square foot) in any given country. Similarly, using the average wage rate of the country in question, (allowing for a certain proportion of higher skilled labour for welding and plastering) a labour cost per square metre (or square foot) can also be arrived at. These two figures can then be used to estimate the cost of the basic F/C hull.

6. CONCLUSIONS

The general conclusion to be drawn from the construction of this prototype vessel is that, given expert supervision, the building of F/C fishing vessels of a good standard is prefectly possible in a developing country. The advantages of low capital cost for yard equipment, a high proportion of unskilled labour and lower hull costs than are needed for equivalent wooden vessels, have all been borne out in practice. Not all the ideas tried out and the methods used in the construction of this vessel were completely satisfactory, and it is of advantage to look at the lessons learnt during the course of construction in order to profit from the experience gained.

With a homogeneous, thin shell structure such as fibre glass reinforced plastic or ferro-cement it would seem logical to use the ship's hull and bulkheads as walls of

tank space, merely adding the necessary interior surfaces to complete the tanks. The storage of diesel fuel in ferro-cement tanks poses a special problem, as diesel oil attacks concrete and cement mortars, and the interior of tanks must be coated with epoxy or diesel resistant tar epoxy tank coatings.

The possible advantages of increased capacity, due to the built-in nature of the tanks and the low cost of construction, made this seem sufficiently attractive to be worth the experiment, and such tanks were incorporated in the design. During the course of construction it was however found that the amount of extra labour involved in fitting the reinforcement, bending the mesh around the many extra interior curves, and the difficulty of forcing the mortar into the corners where the tank joined the hull, together with the cramped working conditions inside the tank space, made the process uneconomic when compared to the construction of conventional steel tanks.

In addition, when the tanks were tested it was found that slow weepage occurred from the tank to the inside of the hull; no doubt due to the difficulty of ensuring that complete penetration of the mesh had been achieved at awkward joints between tank face and hull surface. It is worth noting that no weepage occurred on the outside of the hull, only from the surface of the interior tank face. This leakage could also be attributed to the possibility of seepage along the pipe frames where these passed through the tank face. Because of the destructive nature of diesel oil in contact with cement mortar, it was therefore decided not to continue with this experiment, and the built-in tanks were replaced with steel tanks.

In contrast to this, the insulation of the fish hold by the incorporation of styrofoam sheets glued directly to the hull, with a further layer of mesh and mortar applied on the inside, proved most successful. Due to the absence of frames, this resulted in a fish hold of greater capacity than that possible with wooden construction and with the extra advantage of a smooth, easily cleaned, fish hold lining. However, the heat transfer through ferro-cement in a tropical climate was found to be considerably greater than that of wood, and allowance should be made at the design stage for foam insulation of a thickness of at least one and a half times that normally used in an equivalent wooden hull.

Noise transfer could also prove a problem where below deck accommodation is planned to be located adjacent to the engine room. This can, however, be readily overcome if provision is made for a sound insulating material to be fixed to the bulkheads and under deck. Fixing of such material to a ferro-cement surface can normally be quickly and easily accomplished by gluing with a suitable adhesive. Coamings for the deckhouse of this vessel were of wood, bolted through the ferro-cement deck. Hatch coamings, by contrast, were constructed of upstands of ferro-cement. It is considered that the latter method is preferable and should also be used for deckhouse coamings in further construction.

Wooden rubbing strakes for this vessel were through bolted to the hull. The hull was drilled for bolts with special concrete drills, but although this method proved successful it was time consuming and, in further construction, bolt holes should be located and plugs fitted before plastering. In series production of a standard vessel considerable time can be saved by plastering around plugs which, when removed, leave the bolt holes correctly positioned. The best method of doing this was found to be by the use of scrap round iron bar of the same diameter as the bolt required. This was then covered with a layer of paper and fixed in the correct position in the mesh. After plastering the iron bar can be easily removed and the paper cleaned out, leaving a hole slightly larger than the bolt, which is then sealed in place by the use of caulking compound smeared on the bolt, and used liberally with a grommet of caulking cotton both under washer and head of bolt.

It should be emphasized that the most important process in the construction and the one requiring the most care in workmanship, together with meticulous supervision,

is the application of the mortar to the mesh reinforcement. Despite the greatest care, some small voids may occur, but if these are located and treated as described in Section 3.9 a strong watertight hull will result. Proof of this is demonstrated by the 16 metre F/C vessel which, with a well constructed hull, and with only one coat of a tar epoxy coating and one of antifouling on the bottom, showed absolutely no sign of leakage or dampness in any part of the hull.

From a strength point of view, the main disadvantage of an F/C hull is the resistance to point impact loads - this is liable to be lower than that of an equivalent wooden vessel. As this type of impact is likely to be of frequent occurrence in crowded fishing harbours in developing countries, investigation into possible methods of improving impact resistance should be made. In addition, large, well placed rubbing strakes at deck level and rail cap with the type of protection of bulwarks used on the 16 metre vessel in the region of the trawl doors could be carried right around the hull to minimize risk of damage.

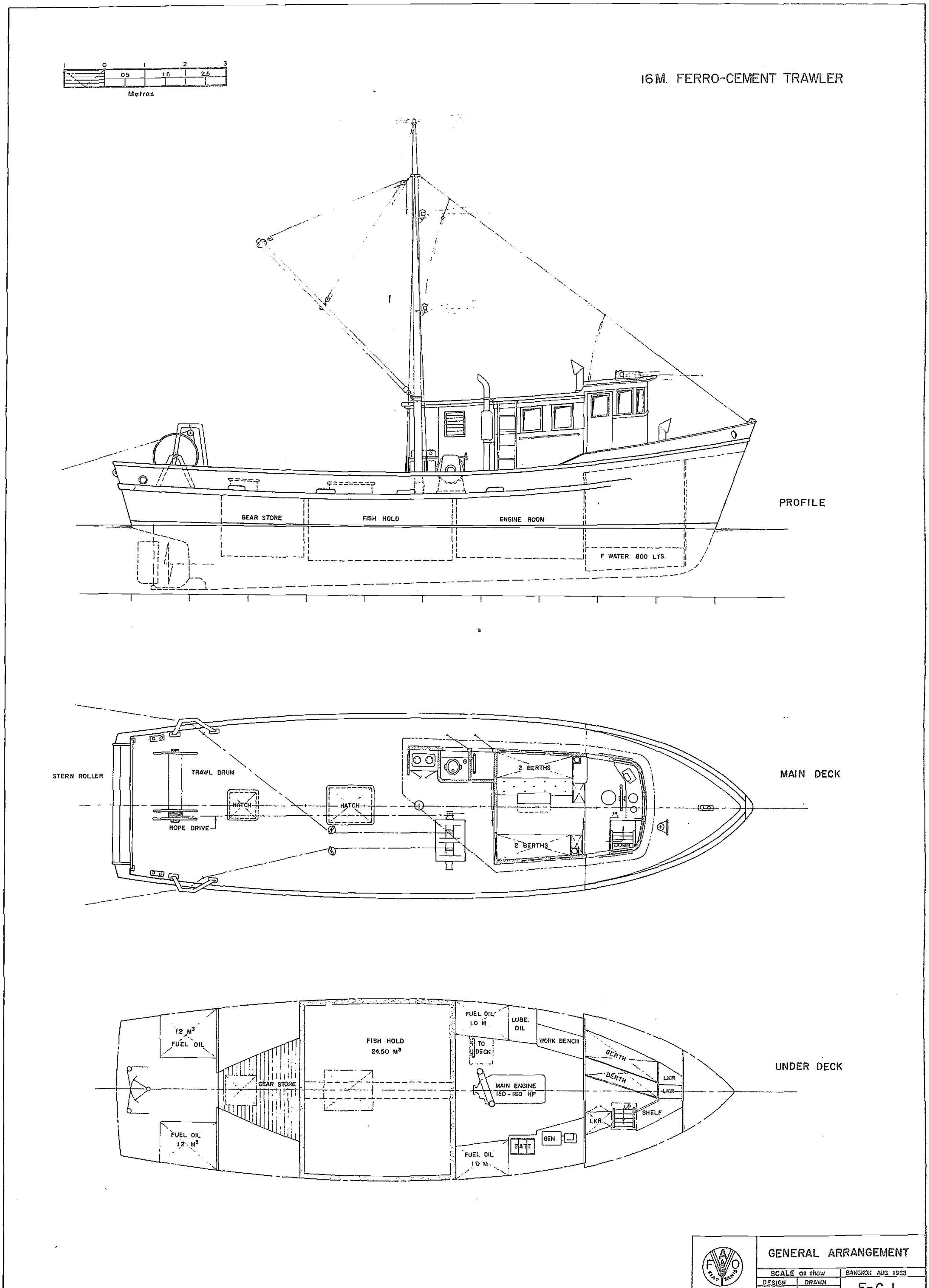
Much has been written and claimed by some builders on the importance of a special secret formula for the mortar mixture. It is considered that the importance given to the mixture has been over-rated. Any correctly proportioned mix with a suitable sulphate resistant cement and a well graded sand or crushed aggregate, together with commercially available additives to reduce water contact and improve workability, should provide a suitable mix with adequate strength properties for boat construction.

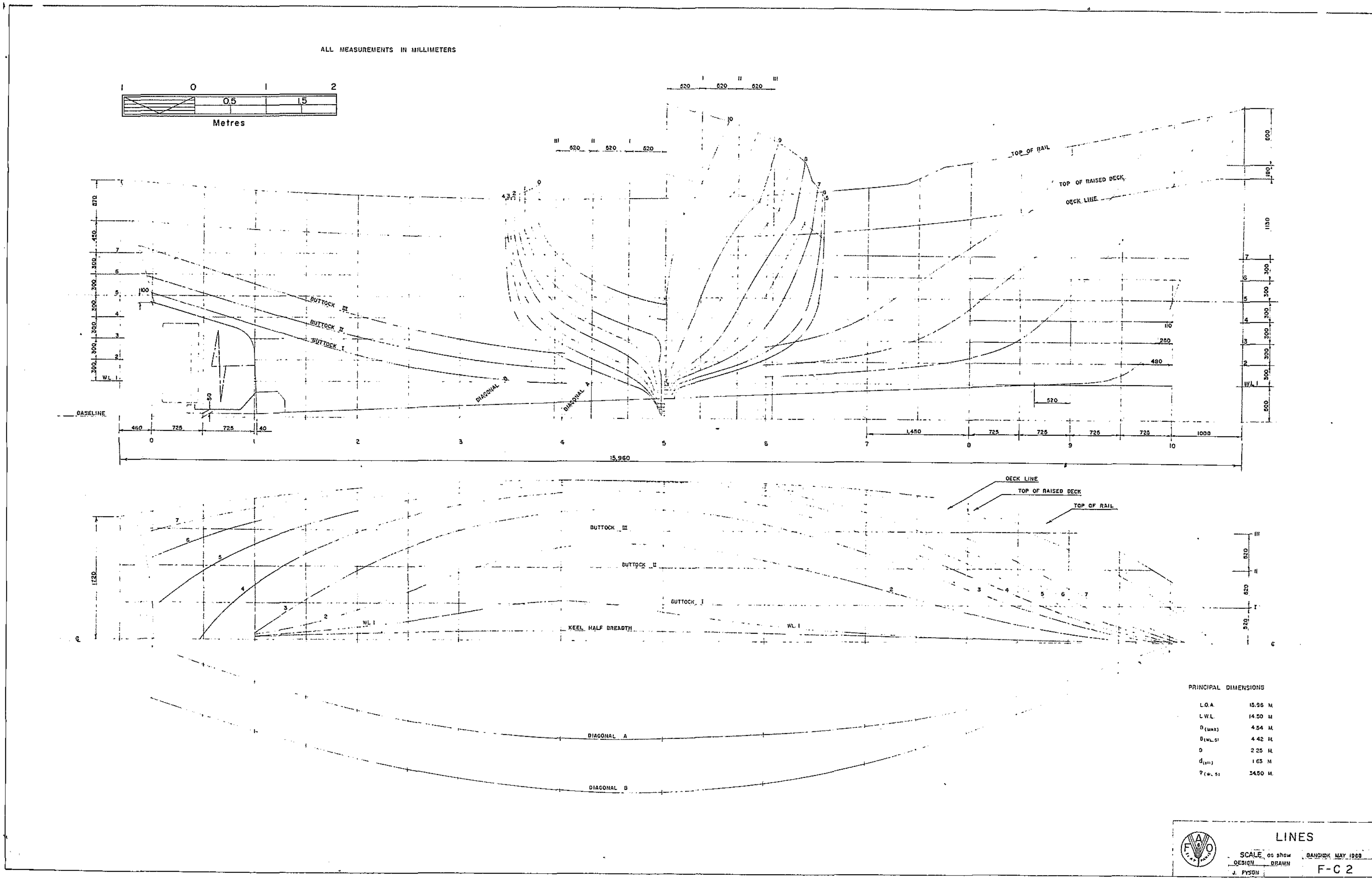
The use of pozzolans has also been given an almost mystical importance by some writers. The main purpose of the pozzolans, apart from reducing the quantity and hence cost of cement, (a minor consideration in the quantities used in boat construction), is to provide an increased sulphate resistance to the final mixture. If a pozzolan is not readily available, the same effect can also be obtained by using a suitable cement with sulphate resistant properties - a Portland type 5 for example.

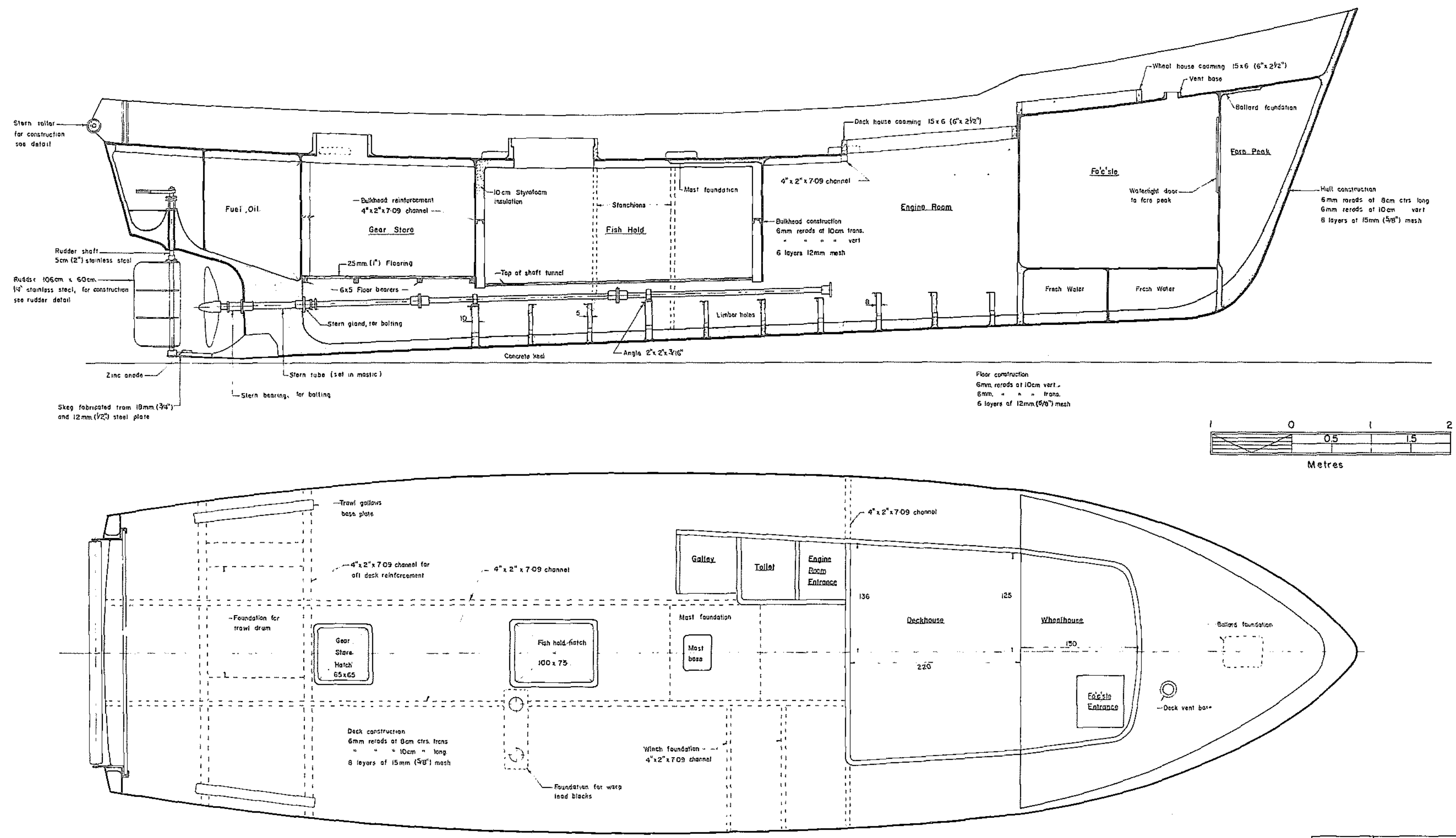
What will have a much more significant effect on strength, is the correct choice of reinforcement and the choice of a suitable weight of steel per unit weight of ferro-cement. The results of tests carried out by the Applied Scientific Research Corporation of Thailand and others indicate that welded square mesh, for example, will give higher strength values for an equivalent weight of steel than will hexagonal wire mesh with, however, more difficulty in "wrapping" the mesh around compound curves and more care needed in avoiding excessive thickness build-up in the laps.

The choice of weight of steel reinforcement per unit weight of ferro-cement should be considered as a design problem which must be solved in accordance with the stresses likely to be encountered in the particular hull under consideration. An example of this is the use of a greater weight of steel in the flatter sections of the forebody of the 16 metre F/C hull. This area of the forebody is subject to greater stresses than the midship sections of the hull; the maximum dynamic loads being of the order of twice those amidships. In addition, experiments carried out by the Technical University of Norway and Det Norske Veritas on bending moments of different frame configurations have shown that maximum moments of frames where the straight part is relatively long are much greater than those with considerable curvature. Accordingly, it would appear logical to design for greater stresses by increasing the steel concentration in critical areas.

For future design work, test results on F/C panels should be applied to the preparation of a standard specification in which a definite weight of steel reinforcement can be specified for any required design stress.


Metres
16M. FERRO-CEMENT TRAWLER
PROFILE
GEAR STORE
FISH HOLD
ENGINE ROOM
F WATER 800 LTS.
MAIN DECK
STERN ROLLER
TRAWL DRUM
HATCH
HATCH
ROPE DRIVE
2 BERTHS
2 BERTHS
UNDER DECK
1.2 M³ FUEL OIL
FUEL OIL 1.2 M³
GEAR STORE
FISH HOLD 24.50 M³
FUEL OIL 1.0 M
LUBE. OIL
WORK BENCH
TO DECK
MAIN ENGINE 150 - 180 HP
BATT
GEN
FUEL OIL 1.0 M
BERTH
BERTH
LKR
LKR
LKR
UP
SHELF
GENERAL ARRANGEMENT
SCALE as show
BANGKOK AUG 1968
DESIGN
DRAWN
J. FYSON
J. FYSON
F-C. 1

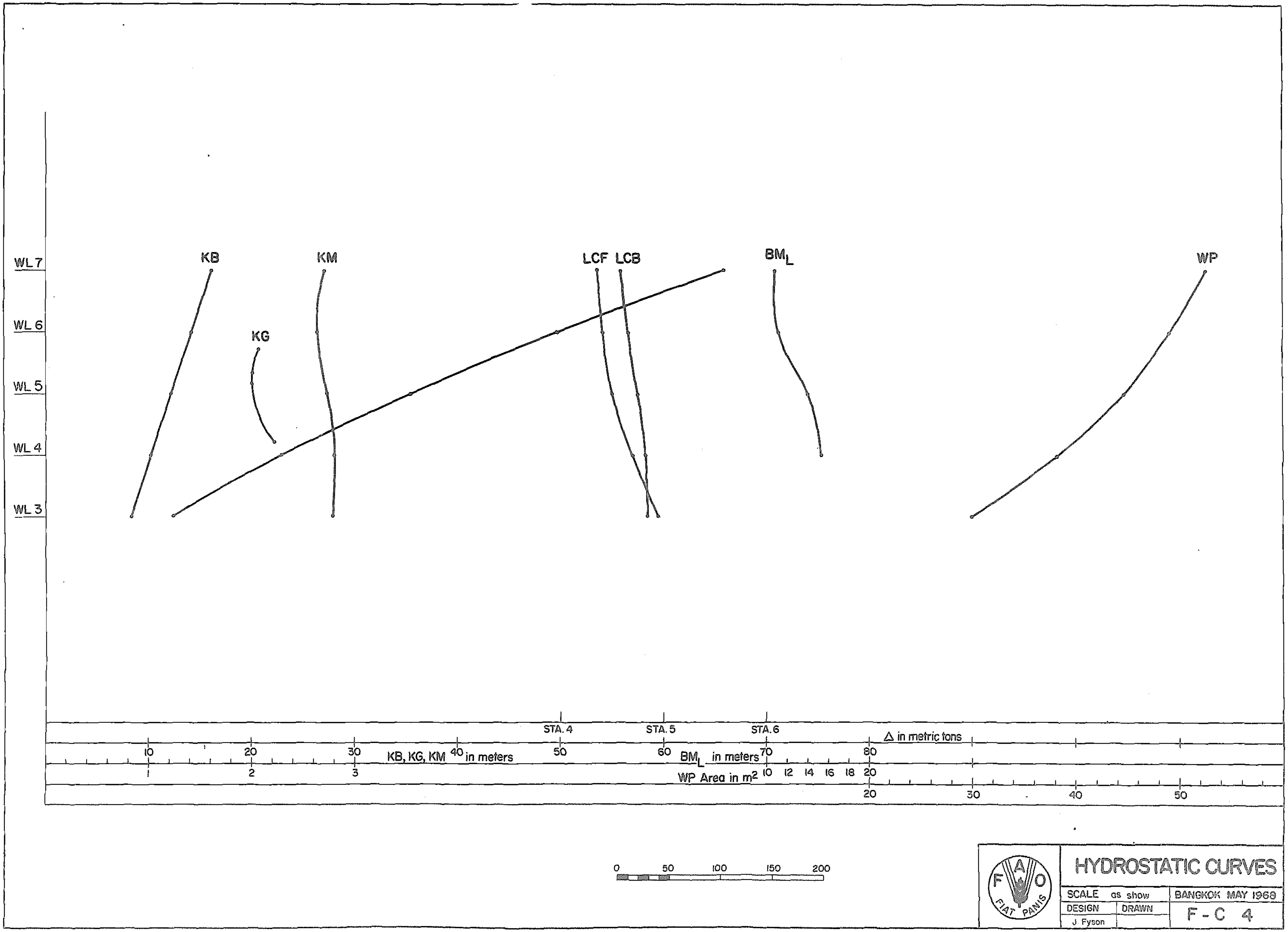

ALL MEASUREMENTS IN MILLIMETERS
Metres
TOP OF RAIL
TOP OF RAISED DECK
DECK LINE
BUTTOCK III
BUTTOCK II
BUTTOCK I
DIAGONAL A
DIAGONAL B
BASELINE
WL 1
KEEL HALF BREADTH
15,960
PRINCIPAL DIMENSIONS
L.O.A. 15.96 M.
L.W.L. 14.50 M.
B (MAX) 4.54 M.
B (WL 5) 4.42 M.
D 2.25 M.
d (aft) 1.63 M.
∇ (WL 5) 34.50 M.
LINES
SCALE as show
BANGKOK MAY 1968
DESIGN
DRAWN
J. FYSON
F-C 2

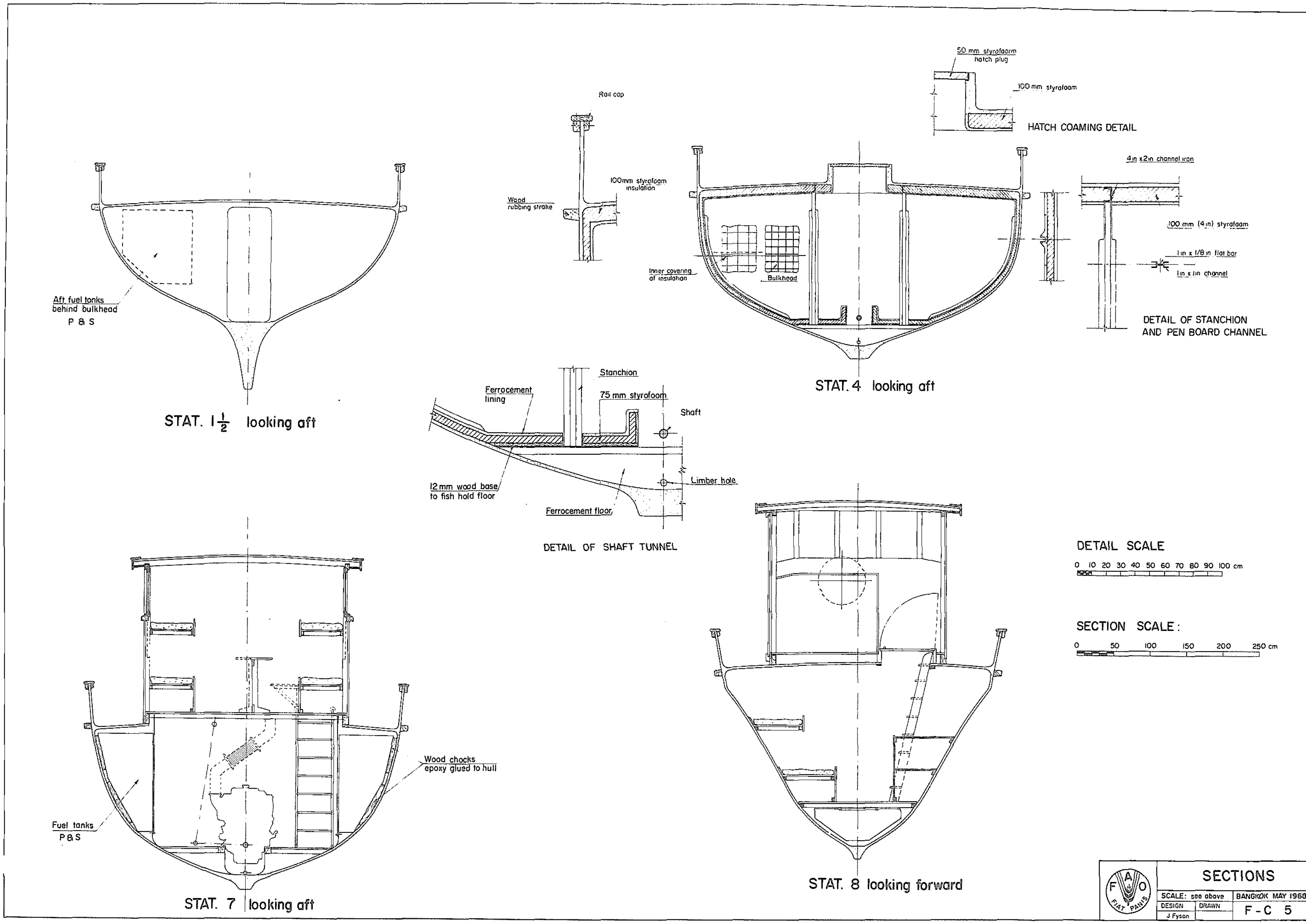


CONSTRUCTION

SCALE as show	BANGKOK AUG. 1969
DESIGN J. FYSON	DRAWN J.F

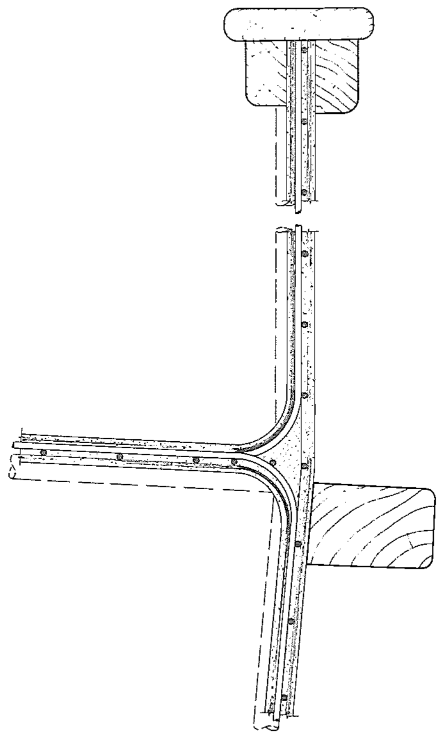
F-C-3


KB
KG
KM
LCF
LCB
BM_L
WP
WL 7
WL 6
WL 5
WL 4
WL 3
STA. 4
STA. 5
STA. 6
Δ in metric tons
10 20 30 40 50 60 70 80
KB, KG, KM in meters
BM_L in meters
1 2 3
WP Area in m²
10 12 14 16 18 20
20 30 40 50
0 50 100 150 200
F A O
FIAT PANIS
HYDROSTATIC CURVES
SCALE as show
BANGKOK MAY 1968
DESIGN
DRAWN
J Fyson
F - C 4

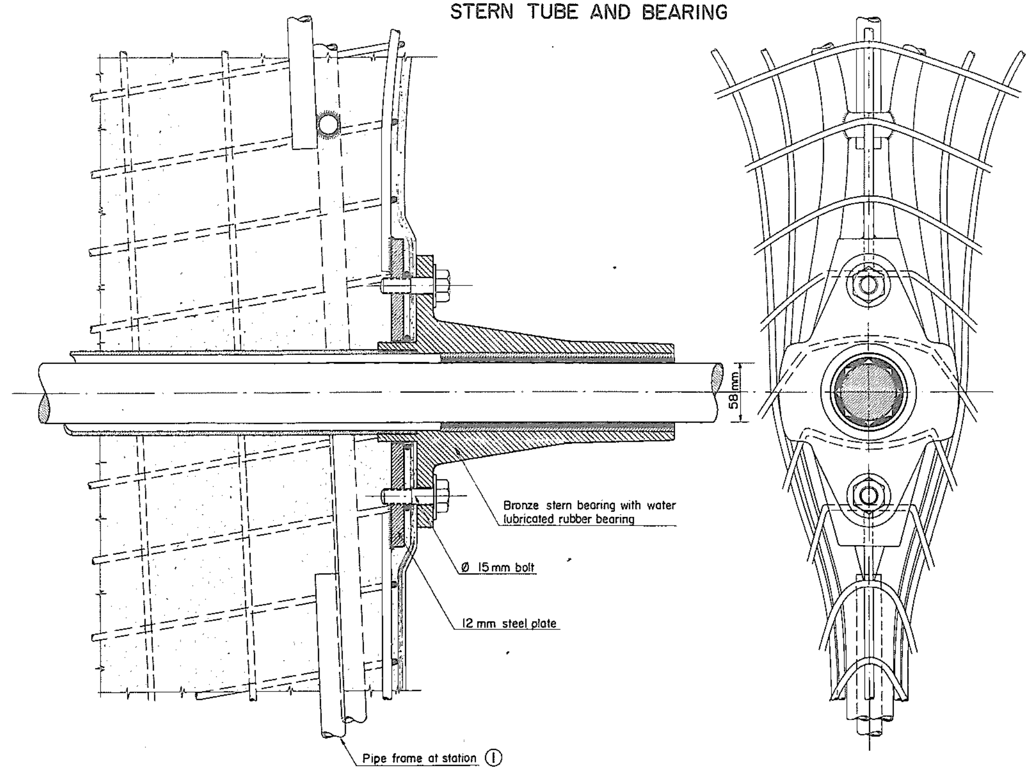


Aft fuel tanks
behind bulkhead
P & S
STAT. 1 1/2 looking aft
Rail cap
Wood
rubbing strake
100mm styrofoam
insulation
Inner covering
of insulation
Bulkhead
50 mm styrofoam
hatch plug
100 mm styrofoam
HATCH COAMING DETAIL
STAT. 4 looking aft
4 in x 2 in channel iron
100 mm (4 in) styrofoam
1 in x 1/8 in flat bar
1 in x 1 in channel
DETAIL OF STANCHION
AND PEN BOARD CHANNEL
Ferrocement
lining
Stanchion
75 mm styrofoam
Shaft
Limber hole
12 mm wood base
to fish hold floor
Ferrocement floor
DETAIL OF SHAFT TUNNEL
Wood chocks
epoxy glued to hull
Fuel tanks
P & S
STAT. 7 looking aft
STAT. 8 looking forward
DETAIL SCALE
0 10 20 30 40 50 60 70 80 90 100 cm
SECTION SCALE :
0 50 100 150 200 250 cm
FAO
FIAT PANIS
SECTIONS
SCALE: see above
BANGKOK MAY 1968
DESIGN
DRAWN
J Fyson
F - C 5

DECK EDGE AND RAIL

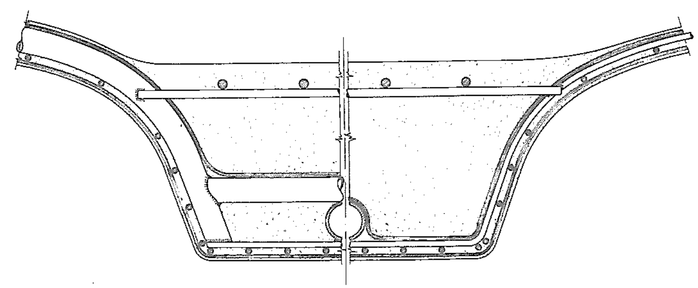


STERN TUBE AND BEARING

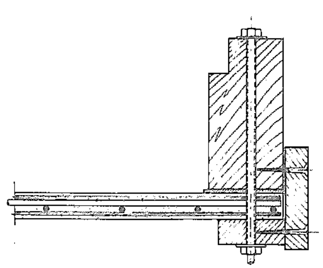


DETAIL SCALE

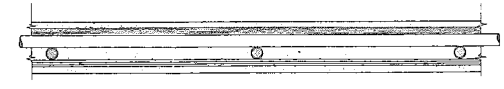
0 2 4 6 8 10 20 30 cm



SECTION THROUGH KEEL

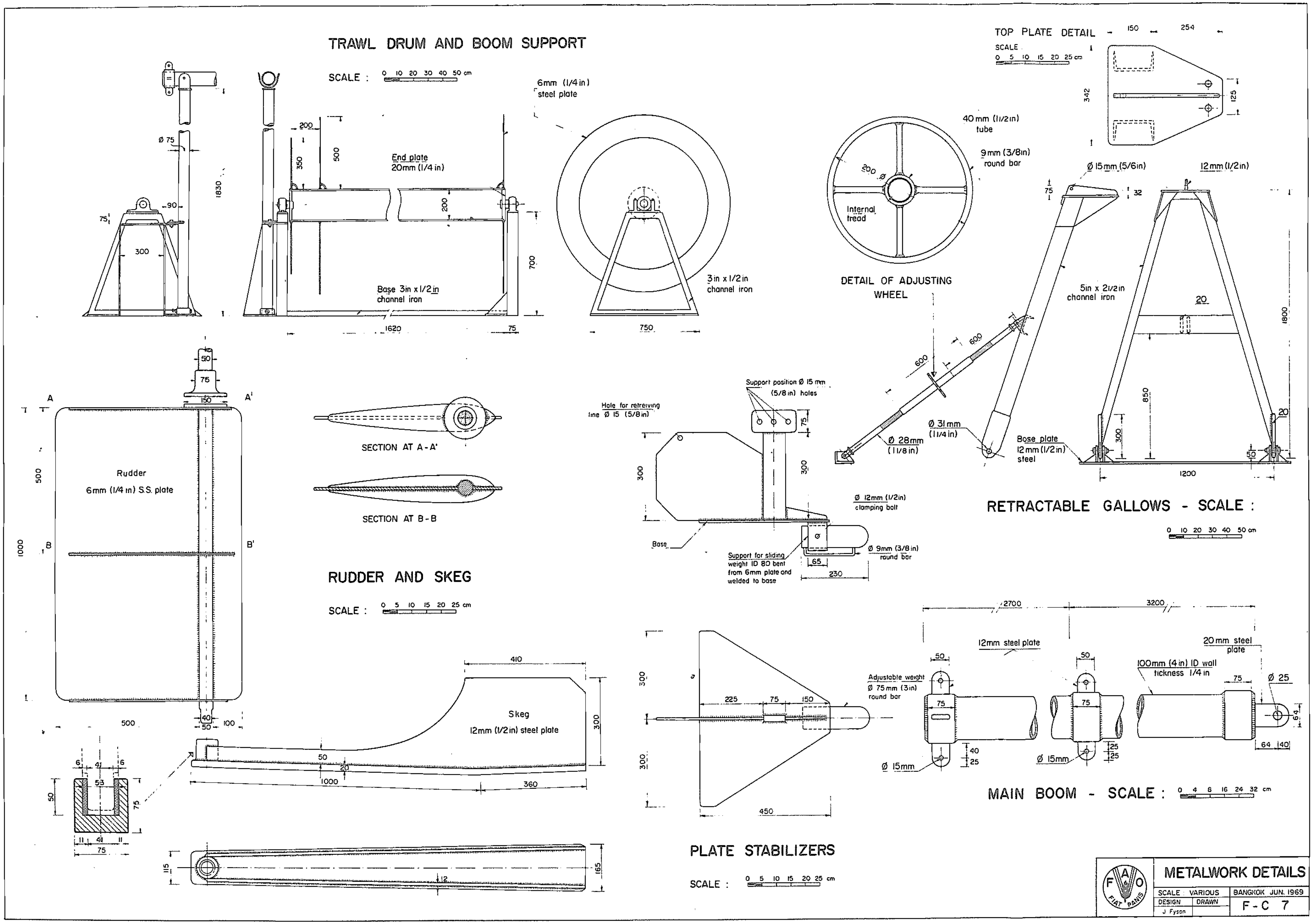


DECKHOUSE COAMING



FERROCEMENT PANEL - SCALE : 0 1 2 3 4 5 cm

FAO FIAT PANIS	FERROCEMENT DETAILS		
	SCALE VARIOUS		BANGKOK JUN 1969
	DESIGN J Fyson	DRAWN	F-C 6



TRAWL DRUM AND BOOM SUPPORT
SCALE : 0 10 20 30 40 50 cm
6mm (1/4 in) steel plate
End plate 20mm (1/4 in)
Base 3in x 1/2 in channel iron
3in x 1/2 in channel iron
1830
1620
750
700
TOP PLATE DETAIL
SCALE 0 5 10 15 20 25 cm
40 mm (1 1/2 in) tube
9 mm (3/8 in) round bar
Internal tread
DETAIL OF ADJUSTING WHEEL
Ø 15 mm (5/6 in)
12 mm (1/2 in)
5in x 2 1/2 in channel iron
Ø 31 mm (1 1/4 in)
Ø 28mm (1 1/8 in)
Base plate 12 mm (1/2 in) steel
RETRACTABLE GALLOWS - SCALE :
0 10 20 30 40 50 cm
Rudder 6mm (1/4 in) S.S. plate
SECTION AT A - A'
SECTION AT B - B
RUDDER AND SKEG
SCALE : 0 5 10 15 20 25 cm
Skeg 12mm (1/2 in) steel plate
Hole for retreiving line Ø 15 (5/8 in)
Support position Ø 15 mm (5/8 in) holes
Ø 12mm (1/2 in) clamping bolt
Ø 9mm (3/8 in) round bar
Base
Support for sliding weight ID 80 bent from 6mm plate and welded to base
PLATE STABILIZERS
SCALE : 0 5 10 15 20 25 cm
12mm steel plate
20 mm steel plate
100mm (4 in) ID wall tickness 1/4 in
Adjustable weight Ø 75 mm (3 in) round bar
Ø 15mm
Ø 25
MAIN BOOM - SCALE : 0 4 8 16 24 32 cm
METALWORK DETAILS
SCALE VARIOUS
DESIGN
DRAWN
J. Fyson
BANGKOK JUN. 1969
F - C 7

FAO FISHERIES TECHNICAL PAPER

This is one of a series of Technical Papers (see inside front cover) dealing with aspects of the work of the FAO Department of Fisheries, Fishery Resources and Exploitation Division, including the review of pertinent information on particular topics, to meet the request for assistance, for presentation to technical and scientific meetings, etc. Extra copies can be obtained by application to:

Biological Data Section
Fishery Resources and Exploitation Division
FAO, 00100 Rome, Italy

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